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INTRODUCTION AND SUCCESSION OF VERTEBRATE LIFE IN AMERICA.[1]

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THE origin of life and the order of succession in which its various forms have appeared upon the earth offer to science its most inviting and most difficult field of research. Although the primal origin of life is unknown, and may perhaps never be known, yet no one has a right to say how much of the mystery now surrounding it science cannot remove. It is certainly within the domain of science to determine when the earth was first fitted to receive life, and in what form the earliest life began. To trace that life in its manifold changes through past ages to the present is a more difficult task, but one from which modern science does not shrink. In this wide field, every earnest effort will meet some degree of success; every year will add new and important facts; and every generation will bring to light some law, in accordance with which ancient life has been changed into life as we see it around us to-day. That such a development has taken place, no one will doubt who has carefully traced any single group of animals through its past history, as recorded in the crust of the earth. The evidence will be especially conclusive, if the group selected belongs to the higher forms of life, which are sensitive to every change in their surroundings. But I am sure I need offer here no argument for evolution; since to doubt evolution to-day is to doubt science, and science is only another name for truth.

Taking, then, evolution as a key to the mysteries of past life on the earth, I invite your attention to the subject I have chosen: "The Introduction and Succession of Vertebrate Life in America."

In the brief hour allotted to me, I could hardly hope to give more than a very incomplete sketch of what is now known on this subject.

[1] An address delivered before the American Association for the Advancement of Science, at Nashville, Tenn., August 30, 1877, by Prof. O. C. Marsh, Vice-President.

I shall, therefore, pass rapidly over the lower groups, and speak more particularly of the higher vertebrates, which have an especial interest for us all, in so far as they approach man in structure, and thus indicate his probable origin. These higher vertebrates, moreover, are most important witnesses of the past, since their superior organization made them ready victims to slight climatic changes, which would otherwise have remained unrecorded.

In considering the ancient life of America, it is important to bear in mind that I can only offer you a brief record of a few of the countless forms that once occupied this continent. The review I can bring before you will not be like that of a great army, when regiment after regiment with full ranks moves by in orderly succession, until the entire host has passed. My review must be more like the roll-call after a battle, when only a few scarred and crippled veterans remain to answer to their names. Or, rather, it must resemble an array of relics, dug from the field of some old Trojan combat, long after the contest, when no survivor remains to tell the tale of the strife. From such an ancient battle-field, a Schliemann might unearth together the bronze shield, lance-head, and gilded helmet, of a prehistoric leader, and learn from them with certainty his race and rank. Perhaps the skull might still retain the barbaric stone weapon by which his northern foe had slain him. Near by, the explorer might bring to light the commingled coat-of-mail and trappings of a horse and rider, so strangely different from the equipment of the chief as to suggest a foreign ally. From these, and from the more common implements of war that fill the soil, the antiquary could determine, by patient study, what nations fought, and perhaps when and why.

By this same method of research the more ancient strata of the earth have been explored, and in our Western wilds veritable battle-fields, strewed with the fossil skeletons of the slain, and guarded faithfully by savage superstition, have been despoiled, yielding to science treasures more rare than bronze or gold. Without such spoils, from many fields, I could not have chosen the present theme for my address to-night.

According to present knowledge, no vertebrate life is known to have existed on this continent in the Archæan, Cambrian, or Silurian period; yet during this time more than half of the thickness of American stratified rocks was deposited. It by no means follows that vertebrate animals of some kind did not exist here in those remote ages. Fishes are known from the Upper Silurian of Europe, and there is every probability that they will yet be discovered in our strata of the same age, if not at a still lower horizon.

In the shore-deposits of the early Devonian sea, known as the Schoharie Grit, characteristic remains of fishes were preserved, and in the deeper sea that followed, in which the Corniferous limestone was

laid down, this class was well represented. During the remainder of the Devonian, fishes continue abundant in the shallower seas, and, so far as now known, were the only type of vertebrate life. These fishes were mainly Ganoids, a group represented in our present waters by the gar-pike (*Lepidosteus*) and Sturgeon (*Acipenser*), but, in the Devonian sea, chiefly by the Placoderms, the exact affinities of which are somewhat in doubt. With these were Elasmobranchs, or the Shark tribe, and among them a few Chimæroids, a peculiar type, of which one or two members still survive. The Placoderms were the monarchs of the ocean. All were well protected by a massive coat of armor, and some of them attained huge dimensions. The American Devonian fishes now known are not so numerous as those of Europe, but they were larger in size, and mostly inhabitants of the open sea. Some twenty genera and forty species have been described.

The more important genera of Placoderms are—*Dinichthys*, *Aspidichthys*, and *Diplognathus*, our largest Palæozoic fishes. Others are —*Acanthaspis*, *Acantholepis*, *Coccosteus*, *Macropetalichthys*, and *Onychodus*. Among the Elasmobranchs were—*Cladodus*, *Ctenacanthus*, *Machæracanthus*, *Rhynchodus*, and *Ptyctodus*, the last two being regarded as Chimæroids. In the Chemung epoch, the great Dipterian family was introduced with *Dipterus*, *Heliodus*, and possibly *Ceratodus*. Species of the European genera, *Bothriolepis* and *Holoptychius*, have likewise been found in our Devonian deposits.

With the close of the Devonian, came the almost total extinction of the great group of Placoderms, while the Elasmobranchs, which had hitherto occupied a subordinate position, increase in numbers and size, and appear to be represented by Sharks, Rays, and Chimæras. Among the members of this group from the Carboniferous, were numerous Cestracionts,[1] species of *Cochliodus* of large size, with others of the genera *Deltodus*, *Helodus*, *Psammodus*, and *Sandalodus*. Of the Petalodonts there were *Antliodus*, *Chomatodus*, *Ctenoptychius*, *Petalodus*, and *Petalorhynchus ;* and of the Hybodonts,[2] the genera *Cladodus*, *Carcharopsis*, and *Diplodus*. These Elasmobranchs were the rulers of the Carboniferous open sea, and more than one hundred species have been found in the lower part of this formation alone. The Ganoids, although still abundant, were of smaller size, and denizens of the more shallow and confined waters. The latter group of fishes was represented by true Lepidostidæ, of the genera *Palæoniscus*, *Amblypterus*, *Platysomus*, and *Eurylepis*. Other genera are —*Rhizodus*, *Megalichthys*, *Ctenodus*, *Edestus*, *Orodus*, *Ctenacanthus*, *Gyracanthus*, and *Cœlacanthus*. Most of these genera occur also in Europe.

From the Permian rocks of America no vertebrate remains are

[1] (*Cestracion* = sharp tool)—a group of sharks, so named from their denticulated dorsal spines.

[2] (*Hybodus* = hump-tooth)—a group of sharks.

known, although in the same formation of Europe Ganoids are abundant; and with them are remains of sharks, and some other fishes, the affinities of which are doubtful. The Palæozoic fishes at present known from this country are quite as numerous as those found in Europe.

In the Mesozoic age, the fishes of America begin to show a decided approach to those of our present waters. From the Triassic rocks, Ganoids only are known, and they are all more or less closely related to the modern gar-pike, or *Lepidosteus*. They are of small size, and the number of individuals preserved is very large. The characteristic genera are—*Catopterus*, *Ischypterus*, *Ptycholepis*, *Rhabdolepis*, and *Turseodus*. From the Jurassic deposit no remains of fishes are known,[1] but in the Cretaceous, ichthyic life assumed many and various forms; and the first representatives of the Teleosts, or bony fishes, the characteristic fishes of to-day, make their appearance. In the deep open sea of this age, Elasmobranchs were the prevailing forms, Sharks and Chimæroids being most numerous. In the great inland Cretaceous sea of North America, true osseous fishes were most abundant, and among them were some of carnivorous habits and immense size. The more sheltered bays and rivers were shared by the Ganoids and Teleosts, as their remains testify. The more common genera of Cretaceous Elasmobranchs were—*Otodus*, *Oxyrhina*, *Galeocerdo*, *Lamna*, and *Ptychodus*. Among the osseous fishes, *Beryx*, *Enchodus*, *Portheus*, and *Saurocephalus*, were especially common, while the most important genus of Ganoids was *Lepidotus*.

The Tertiary fishes are nearly all of modern types, and from the beginning of this period there was comparatively little change. In the marine beds, Sharks, Rays, and Chimæroids, maintained their supremacy, although Teleosts were abundant, and many of them of large size. The Ganoids were comparatively few in number. In the earliest Eocene fresh-water deposits, it is interesting to find that the modern Gar-pike, and *Amia*, the dogfish of our Western lakes, which by their structure are seen to be remnants of a very early type, are well represented by species so closely allied to them that only an anatomist could separate the ancient from the modern. In the succeeding beds, these fishes are still abundant, and with them are Siluroids nearly related to the modern catfish (*Pimelodus*). Many small fishes, allied apparently to the modern herring (*Clupea*), left their remains in great numbers in the same deposits, and, with them has been recently found a landlocked ray (*Heliobatis*).

The almost total absence of remains of fishes from the Miocene lake-basins of the West is a remarkable fact, and perhaps may best be explained by the theory that these inland waters, like many of the smaller lakes in the same region to-day, were so impregnated with mineral matters as to render the existence of vertebrate life in them

[1] A species of *Ceratodus* has recently been found in the upper Jurassic of Colorado, and named by the writer *C. Güntheri*.—O. C. M.

impossible. No one who has tasted such waters, or has attempted to ford one of the modern alkaline lakes which are often met with on the present surface of the same deposits, will doubt the efficiency of this cause, or the easy entombment of the higher vertebrates that ventured within their borders. In the Pliocene lake-basins of the same region, remains of fishes were not uncommon, and in some of them are very numerous. These are all of modern types, and most of them are Cyprinoids, related to the modern carp. The Post-pliocene fishes are essentially those of to-day.

In this brief synopsis of the past ichthyic life of this continent, I have mentioned only a few of the more important facts, but sufficient, I trust, to give an outline of its history. Of this history, it is evident that we have as yet only a very imperfect record. We have seen that the earliest remains of fishes known in this country are from the lower Devonian; but these old fishes show so great a diversity of form and structure as to clearly indicate for the class a much earlier origin. In this connection, we must bear in mind that the two lowest groups of existing fishes are entirely without osseous skeletons, and hence, however abundant, would leave no permanent record in the deposits in which remains of fishes are usually preserved. It is safe to infer, from the knowledge which we now possess of the simpler forms of life, that even more of the early fishes were cartilaginous, or so destitute of hard parts as to leave no enduring traces of their existence. Without positive knowledge of such forms, and considering the great diversity of those we have, it would seem a hopeless task at present to attempt to trace successfully the genealogy of this class. One line, however, appears to be direct, from our modern gar-pike, through the lower Eocene *Lepidosteus* to the *Lepidotus* of the Cretaceous, and perhaps on through the Triassic *Ischypterus* and Carboniferous *Palæoniscus;* but beyond this, in our rocks, it is lost. The living Chimæra of our Pacific coast has nearly allied forms in the Tertiary and Cretaceous, more distant relatives in the Carboniferous, and a possible ancestor in the Devonian *Rhynchodus*. Our sharks likewise can be traced with some certainty back to the Palæozoic; and even the *Lepidosiren*, of South America, although its immediate predecessors are unknown, has some peculiar characters which strongly point to a Devonian ancestry. These suggestive lines indicate a rich field for investigation in the ancient life-history of American fishes.

The Amphibians, the next higher class of vertebrates, are so closely related to the fishes in structure that some peculiar forms of the latter have been considered by anatomists as belonging to this group. The earliest evidence of Amphibian existence, on this continent, is in the Sub-Carboniferous, where footprints have been found which were probably made by Labyrinthodonts, the most ancient representatives of the class. Well-preserved remains are abundant

in the Coal-Measures, and show that the Labyrinthodonts differed in important particulars from all modern Amphibians, the group which includes our frogs and salamanders. Some of these ancient animals resemble a salamander in shape, while others were serpent-like in form. None of those yet discovered were frog-like, or without a tail, although the restored Labyrinthodont of the text-books is thus represented. All were protected by large pectoral bony plates, and an armor of small scutes on the ventral surface of the body. The walls of their teeth were more or less folded, whence the name Labyrinthodont. The American Amphibians known from osseous remains are all of moderate size, but the footprints attributed to this group indicate animals larger than any of the class yet found in the Old World. The Carboniferous Amphibians were abundant in the swampy tropical forests of that period, and their remains have been found imbedded in the coal then deposited, as well as in hollow stumps of the trees left standing.

The principal genera of this group from American Carboniferous rocks are—*Sauropus*, known only from footprints, *Baphetes*, *Dendrerpeton*, *Hylonomus*, *Hylerpeton*, *Raniceps*, *Pelion*, *Leptophractus*, *Molgophis*, *Ptyonius*, *Amphibamus*, *Cocytinus*, and *Ceraterpeton*. The last genus occurs also in Europe. Certain of these genera have been considered by some writers to be more nearly related to the lizards, among true reptiles. Some other genera known from fragmentary remains or footprints in this formation have likewise been referred to the true reptiles, but this question can perhaps be settled only by future discoveries.

No Amphibia are known from American Permian strata, but in the Triassic a few characteristic remains have been found. The three genera, *Dictyocephalus*, *Dispelor*, and *Pariostegus*, have been described, but, although apparently all Labyrinthodonts, the remains preserved are not sufficient to add much to our knowledge of the group. The Triassic footprints which have been attributed to Amphibians are still more unsatisfactory, and at present no important conclusions in regard to this class can be based upon them. From the Jurassic and Cretaceous beds of this continent no remains of Amphibians are known. A few only have been found in the Tertiary, and these are all of modern types.

The Amphibia are so nearly allied to the Ganoid fishes that we can hardly doubt their descent from some member of that group. With our present limited knowledge of the extinct forms, however, it would be unprofitable to attempt to trace in detail their probable genealogy.

The authors to whom especial credit is due for our knowledge of American fossil Fishes and Amphibians, are Newberry, Leidy, Cope, Dawson, Agassiz, St. John, Gibbes, Wyman, Redfield, and Emmons, and the principal literature of the subject will be found in their publications.

Reptiles and birds form the next great division of vertebrates, the *Sauropsida*, and of these the reptiles are the older type, and may be first considered. While it may be stated with certainty that there is at present no evidence of the existence of this group in American rocks older than the Carboniferous, there is some doubt in regard to their appearance even in this period. Various footprints which strongly resemble those made by lizards, a few well-preserved remains similar to the corresponding bones in that group, and a few characteristic specimens, nearly identical with those from another order of this class, are known from American Coal-Measures. These facts, and some others which point in the same direction, render it probable that we may soon have conclusive evidence of the presence of true reptiles in this formation, and in our overlying Permian, which is essentially a part of the same series. In the Permian rocks of Europe true reptiles have been found.

The Mesozoic period has been called the Age of Reptiles, and during its continuance some of the strangest forms of reptilian life made their appearance, and became extinct. Near its commencement, while the Triassic shales and sandstones were being deposited, true reptiles were abundant. Among the most characteristic remains discovered are those of the genus *Belodon*, which is well known also in the Trias of Europe. It belongs to the Thecodont division of reptiles, which have teeth in distinct sockets, and its nearest affinities are with the *Crocodilia*, of which order it may be considered the oldest known representative. In the same strata in which the Belodonts occur, remains of Dinosaurs are found, and it is a most interesting fact that these highest of reptiles should make their appearance, even in a generalized form, at this stage of the earth's history. The Dinosaurs, although true reptiles in all their more important characters, show certain well-marked points of resemblance to existing birds of the order *Ratitæ*, a group which includes the ostriches; and it is not improbable that they were the parent-stock from which birds originated.

During Triassic time, the Dinosaurs attained in America an enormous development both in variety of forms and in size. Although comparatively few of their bones have as yet been discovered in the rocks of this country, they have left unmistakable evidence of their presence in the footprints and other impressions upon the shores of the waters which they frequented. The Triassic sandstone of the Connecticut Valley has long been famous for its fossil footprints, especially the so-called "bird-tracks," which are generally supposed to have been made by birds, the tracks of which many of them closely resemble. A careful investigation, however, of nearly all the specimens yet discovered has convinced me that there is not a particle of evidence that any of these fossil impressions were made by birds. Most of these three-toed tracks were certainly not made by birds; but by quadrupeds, which usually walked upon their hind-feet alone,

and only occasionally put to the ground their smaller anterior extremities. I have myself detected the impressions of these anterior limbs in connection with the posterior footprints of nearly all of the supposed "bird-tracks" described, and have little doubt that they will eventually be found with all. These double impressions are precisely the kind which Dinosaurian reptiles would make, and, as the only characteristic bones yet found in the same rocks belong to animals of this group, it is but fair to attribute all these footprints to Dinosaurs, even where no impressions of fore-feet have been detected, until some evidence appears that they were made by birds. I have no doubt that birds existed at this time, although at present the proof is wanting.

The principal genera of Triassic reptiles known from osseous remains in this country are—*Amphisaurus* (*Megadactylus*), from the Connecticut Valley; *Bathygnathus*, from Prince Edward's Island; *Belodon*, and *Clepsysaurus*. Other generic names which have been applied to footprints and to fragmentary remains need not here be enumerated. A few remains of reptiles have been found in undoubted Jurassic rocks of America, but they are not sufficiently well determined to be of service in this connection.[1] Others have been reported from supposed Jurassic strata, which are now known to be Cretaceous. It will thus be seen that, although reptilian life was especially abundant during the Triassic and Jurassic periods, but few bones have been found. This is owing in part to the character of most of the rocks then formed, which were not well fitted for preserving such remains, although admirably adapted to retain footprints.

During the Cretaceous period, reptilian life in America attained its greatest development, and the sediments laid down in the open seas and estuaries were usually most favorable for the preservation of a faithful record of its various phases. Without such a perfect matrix as some of these deposits afford, many of the most interesting vertebrates recently brought to light from this formation would probably have remained unknown. The vast extent of these beds insures, moreover, many future discoveries of interest.

In the lowest Cretaceous strata of the Rocky Mountain region, the Dakota group, part of which at least represents the Wealden of Europe, remains of *Chelonia*, or Turtles, Crocodiles, and Dinosaurs occur, the last being especially abundant. The *Chelonia*, although known from the Jurassic of Europe, here appear for the first time in American rocks. Some of the earliest forms are allied to the modern genus *Trionyx*. In the higher Cretaceous beds, some Chelonians of enormous size have been found. They belong to the genus *Atlantochelys*, which has the ribs separate, as in the existing *Sphargis*,[2]

[1] Since this address was delivered, I have determined the beds containing gigantic Dinosaurs, on the flanks of the Rocky Mountains, to be upper Jurassic, and called them Atlantosaurus Beds. (*See* frontispiece, section.) These strata were formerly referred to the Dakota group, or base of the Cretaceous.—O. C. M.

[2] *Sphargis*, a genus of turtles inhabiting the Atlantic and Mediterranean. They are

and presents other embryonic characters. A few genera appear to be related to the modern genus *Chelone*. The remaining Cretaceous species were mostly of the Emydoid[1] type; and others were related to *Chelydra*. The more important genera of Cretaceous Chelonians known from characteristic specimens are—*Atlantochelys* (*Protostega*), *Adocus*, *Bothremys*, *Compsemys*, *Plastomenus*, *Osteopygis*, *Propleura*, *Lytoloma*, and *Taphrosphys*. Most of these genera were represented by several species, and the individuals were numerous. No land-tortoises have as yet been found in this formation. In American Tertiary deposits, Chelonians are abundant, especially in the fresh-water beds. They all show near affinities with modern types, and most of them can be referred to existing genera. In the Tertiary lake-basins of the West, land-tortoises are very numerous, and with them are many fresh-water forms of *Trionyx* and allied genera.

A striking feature of the American Cretaceous fauna, as contrasted with that of Europe, is the almost entire absence in our strata of species of *Ichthyosaurus* and *Plesiosaurus*, which abound in many other regions, but here seem to be replaced by the Mosasaurs. A few fragmentary remains have indeed been referred to these genera, but the determination may fairly be questioned. This is more than true of the proposed new order *Streptosauria*, which was founded wholly on error. The order *Plesiosauria*, however, is well represented, but mainly by forms more nearly related to the genus *Pliosaurus* than to the type of the group. These were marine reptiles, all of large size, while some of them attained vast dimensions. So far as at present identified, they may be referred to the genera *Cimoliosaurus*, *Discosaurus* (*Elasmosaurus*), and *Pliosaurus*. The number of species is comparatively few, and none are known above the Cretaceous. The important suggestion of Gegenbaur, that the *Halisauria*, which include the Plesiosaurs, branched off from the fishes before the Amphibians, finds some support in American specimens recently discovered.

The Reptiles most characteristic of our American Cretaceous strata are the *Mosasauria*, a group with very few representatives in other parts of the world. In our Cretaceous seas, they ruled supreme, as their numbers, size, and carnivorous habits, enabled them to easily vanquish all rivals. Some were at least sixty feet in length, and the smallest ten or twelve. In the inland Cretaceous sea from which the Rocky Mountains were beginning to emerge, these ancient "sea-serpents" abounded; and many were entombed in its muddy bottom. On one occasion, as I rode through a valley washed out of this old ocean-bed, I saw no less than seven different skeletons of these mon-

the largest of all turtles, and have the body covered with a thick coriaceous skin instead of a hard shell.

[1] *Emys*, a genus of small land and fresh-water tortoises.

sters in sight at once. The Mosasaurs were essentially swimming lizards, with four well-developed paddles, and they had little affinity with modern serpents, to which they have been compared. The species are quite numerous, but they belong to comparatively few genera, of which *Mosasaurus*, *Tylosaurus*, *Lestosaurus*, and *Edestosaurus*, have alone been identified with certainty. The genus *Mosasaurus* was first found in Europe. All the known species of the group are Cretaceous.

The *Crocodilia* are abundant in rocks of Cretaceous age in America, and two distinct types are represented. The older type, which is foreshadowed by *Belodon* of the Trias, has biconcave vertebræ, and shows marked affinities with the genus *Teleosaurus*, from the Jura of Europe. The best-known genus is *Hyposaurus*, of which there are several species, all more or less resembling in form the modern gavial of the Ganges. A peculiar intermediate form is seen in *Diplosaurus*, from the Wealden of the Rocky Mountains. The second type, which now makes its appearance for the first time, has procœlian [1] vertebræ, and in other respects resembles existing crocodiles. The genera described are *Bottosaurus*, *Holops*, and *Thoracosaurus*, none of which, so far as known, pass above the Cretaceous. Of *Crocodilia* with opisthocœlous [1] vertebræ, America, so far as we know, has none. Specimens similar to those so termed in Europe are not uncommon here, but they pertain to Dinosaurs.

In the Eocene fresh-water beds of the West, Crocodilians are especially abundant, and all, with the exception of *Limnosaurus*, belong apparently to the genus *Crocodilus*, although some species show certain points of resemblance to existing alligators. The Miocene lake-basins of the same region contain no remains of crocodiles, so far as known, and the Pliocene deposits have afforded only a single species. The Tertiary marine beds of the Atlantic coast contain comparatively few Crocodilian remains, and all are of modern types; the genus *Gavialis* having one Eocene species, and the alligator being represented only in the latest deposits.

It is worthy of special mention, in this connection, that no true *Lacertilia*, or Lizards, and no *Ophidia*, or Serpents, have yet been detected in American Cretaceous beds; although their remains, if present, would hardly have escaped observation in the regions explored. The former will doubtless be found, as several species occur in the Mesozoic of Europe; and perhaps the latter, although the Ophidians are apparently a more modern type. In the Eocene lake-basins of Western America, remains of lizards are very numerous, and indicate species much larger than any existing to-day. Some of these,

[1] Vertebræ which have centra concave at each end have been conveniently termed *amphicœlous*; those with a cavity in front and a convexity behind, *procœlous*; where the position of the concavity and convexity is reversed, they are *opisthocœlous*.—(Huxley, "Anatomy of Vertebrated Animals.")

the *Glyptosauridæ*, were protected by a highly-ornamented bony coat-of-mail, and others were covered with scales, like recent lizards. A few resembled, in their more important characters, the modern iguana. The genera best represented in the Eocene are—*Glyptosaurus*, *Iguanavus*, *Oreosaurus*, *Thinosaurus*, *Tinosaurus*, and *Saniva*. Some of these genera appear to have continued into the Miocene, but here, as well as in the Pliocene, few remains of this group have been found. It is not improbable that some of our extinct Reptiles may prove to belong to *Rynchocephala*, but at present this is uncertain. The genus *Notosaurus*, from Brazil, has biconcave vertebræ, and some other characters which point to that group. No Dicynodonts[1] or Theriodonts[2] have as yet been found in this country.

The first American serpents, so far as now known, appear in the Eocene, which contains also the oldest European species. On the Atlantic border, the genus *Titanophis* (*Dinophis*) is represented by several species of large size, one at least thirty feet in length, and all doubtless inhabitants of the sea. In the fresh-water Western Eocene, remains of snakes are abundant, but all are of moderate size. The largest of these were related to the modern boa-constrictors. The genera described are *Boavus*, *Lithophis*, and *Limnophis*. The Miocene and Pliocene snakes from the same region are known only from a few fragmentary remains.

The *Pterosauria*, or flying-lizards, are among the most interesting reptiles of Mesozoic time, and many of them left their remains in the soft sediments of our inland Cretaceous sea. These were veritable dragons, having a spread of wings of from ten to twenty-five feet. They differed essentially from the smaller Pterodactyls found in the Old World, in the entire absence of teeth, showing in this respect a resemblance to modern birds; and they possess other distinctive characters. They have therefore been placed in a new order, *Pteranodontia*, from the typical genus *Pteranodon*, of which five species are known. The only other genus is *Nyctosaurus*, represented by a single species. All the specimens yet found are from essentially the same horizon, in the chalk of Kansas. The reported discovery of remains of this order from older formations in this country is without foundation.

The strange reptiles known as *Dinosauria*, which, as we have seen, were numerous during the deposition of our Triassic shales and sandstones, have not yet been found in American Jurassic,[3] but were well represented here throughout the Cretaceous, and at its close became extinct. These animals possess a peculiar interest to the anato-

[1] Dicynodonts (two canine teeth), a singular group of extinct reptiles from South Africa, India, and the Ural Mountains. The family name alludes to the two enormous canine teeth which grow from the upper jaw.

[2] Theriodonts (beast-tooth), a group of extinct reptiles, having, according to Owen, some characters which point toward the Mammalia.

[3] *See* note on page 520.

mist, since, although reptilian in all their main characters, they show clear affinities with the birds, and have some features which may point to mammals. The Cretaceous Dinosaurs were all of large size, and most of them walked on the hind-feet alone, like modern struthious birds. Two well-marked types may be distinguished among the remains discovered in deposits of this age: the herbivorous forms, represented mainly by *Hadrosaurus*, a near ally of the *Iguanodon* of Europe; and their carnivorous enemies, of which *Dryptosaurus* (*Lælaps*) may be considered typical in this country, and *Megalosaurus* in Europe. Near the base of our Cretaceous formation, in beds which I regard as the equivalent of the European Wealden, the most gigantic forms of this order yet discovered have recently been brought to light. One of these monsters (*Titanosaurus montanus*),[1] from Colorado, is by far the largest land-animal yet discovered; its dimensions being greater than was supposed possible in an animal that lived and moved upon the land. It was some fifty or sixty feet in length, and, when erect, at least thirty feet in height! It doubtless fed upon the foliage of the mountain forests, portions of which are preserved with its remains. With *Titanosaurus*, the bones of smaller Dinosaurs, one (*Nanosaurus*), not larger than a cat, as well as those of crocodiles and turtles, are not uncommon.[2] The recent discovery of these interesting remains, many and various, in strata that had long been pronounced by professional explorers barren of vertebrate fossils, should teach caution to those who decline to accept the imperfection of our knowledge to-day as a fair plea for the supposed absence of intermediate forms.

In the marine Cretaceous beds of the West, only a single Dinosaur (*Hadrosaurus agilis*) has been found, but in the higher fresh-water beds, which mark the close of this formation, their remains are numerous, and indicate several well-marked species if not genera. In the marine beds on the Atlantic coast, the bones of Dinosaurs are frequently met with, and in the Upper Cretaceous Greensand of New Jersey, the type specimens of *Hadrosaurus* and *Dryptosaurus* were found. In Cretaceous fresh-water deposits on the coast of Brazil, remains of this order occur, but the specimens hitherto discovered are not sufficiently characteristic for accurate determination. This is unfortunately true of many Dinosaurian fossils from North America, but the great number of these reptiles which lived here during the Cretaceous Period promises many future discoveries, and substantial additions to our present knowledge of the group.

[1] This generic name proved to be preoccupied, and I have substituted for it, *Atlantosaurus*.—O. C. M.

[2] A new order of huge reptiles (*Stegosauria*), apparently allied to the Dinosaurs and Chelonia, and two new genera of Dinosaurs (*Apatosaurus* and *Allosaurus*), have since been described by the writer from the same Upper Jurassic horizon.—(*American Journal of Science*, December, 1877.)

The first appearance of birds in America, according to our present knowledge, was during the Cretaceous Period, although many announcements have been made of their existence in preceding epochs. The evidence of their presence in the Trias, based on footprints and other impressions, is, at present, as we have seen, without value; although we may confidently await their discovery there, if not in older formations. *Archæopteryx*, from the European Jura, the oldest bird known, and now fortunately represented by more than a single specimen, clearly indicates a much higher antiquity for the class. The earliest American forms at present known are the *Odontornithes*, or birds with teeth, which have been exhumed, within the last few years, from the chalk of Kansas. The two genera *Hesperornis* and *Ichthyornis* are types of distinct orders, and differ from each other and from *Archæopteryx* much more than do any existing birds among themselves; thus showing that Birds are now a closed type, and that the key to the history of the class must be sought for in the distant past.

In *Hesperornis*, we have a large aquatic bird, nearly six feet in length, with a strange combination of characters. The jaws are provided with teeth, set in grooves; the wings were rudimentary and useless; while the legs were very similar to those of modern diving birds. This last feature was merely an adaptation, as the more important characters are struthious, showing that *Hesperornis* was essentially a carnivorous swimming ostrich. *Ichthyornis*, a small flying bird, was stranger still, as the teeth were in sockets, and the vertebræ biconcave, as in fishes and a few reptiles. *Apatornis* and other allied forms occur in the same beds, and probably all were provided with teeth. It is strange that the companions of these ancient toothed birds should have been Pterodactyls without teeth. In the later Cretaceous beds of the Atlantic coast various remains of aquatic birds have been found, but all are apparently distinct from those of the West. The known genera of American Cretaceous birds are—*Apatornis*, *Baptornis*, *Graculavus*, *Hesperornis*, *Ichthyornis*, *Laornis*, *Lestornis*, *Palæotringa*, and *Telmatornis*. These are represented by some twenty species. In Europe, but two species of Cretaceous birds are known, and both are based upon fragmentary specimens.

During the Tertiary period, birds were numerous in this country, and all yet discovered appear to have belonged to modern types. The Eocene species described are mostly wading birds, but here, and in the later Tertiary deposits, some characteristic American forms make their appearance, strongly foreshadowing our present avian fauna. The extinct genera are the Eocene *Uintornis*, related to the woodpeckers, and *Aletornis*, which includes several species of waders. Among the existing genera found in our Tertiary beds are—*Aquila*, *Bubo*, *Meleagris*, *Grus*, *Graculus*, *Puffinus*, and *Catarractes*. The great auk (*Alca impennis*), which was once very abundant on our northeast coast, has become extinct within a few years.

In this brief summary of the past life of reptiles and birds in America, I have endeavored to exclude doubtful forms, and those very imperfectly known, preferring to present the conclusions reached by careful study, incomplete though they be, rather than weary you with a descriptive catalogue of all the fossils to which names have been applied. Even this condensed review can hardly fail to give you some conception of the wealth of our continent in the extinct forms of these groups, and thus to suggest what its actual life must have been.

Although the Trias offers at present the first unquestioned evidence of true reptiles, we certainly should not be justified in supposing for a moment that older forms did not exist. So too in considering the different groups of reptiles, which seem to make their first appearance at certain horizons, flourish for a time, and then decline, or disappear, every day brings evidence to show that they are but fragments of the unraveled strands which converge in the past to form the mystic cord uniting all life. If the attempt is made to follow back any single thread, and thus trace the lineage of a group, we are met by difficulties which the science of to-day can only partially remove. And yet the anatomist constantly sees in the fragments which he studies hints of relationship which are to him sure prophecies of future discoveries.

The genealogy of the *Chelonia* is at present unknown, and our American extinct forms, so far as we now have them, throw little light on their ancestry. This is essentially true, also, of our *Plesiosauria*, *Lacertilia*, and *Ophidia*, although suggestive facts are not wanting to indicate possible lines of descent. With the *Crocodilia*, however, the case seems to be different, and Huxley has clearly pointed out the path for investigation. It is probable that material already exists in our museums for tracing the group through several important steps in its development. We have already seen that the modern procœlian type of this order goes back only to the Upper Cretaceous, while the *Belodonts*, of our Triassic rocks, with their biconcave vertebræ, are the oldest known Crocodilians. Our Jurassic, unfortunately, throws but little light on the intermediate forms, but we know that the line was continued, as it was in the Old World through *Teleosaurus*. The beds of the Rocky Mountain Wealden[1] have just furnished us with a genuine "missing link," a saurian (*Diplosaurus*) with essentially the skull and teeth of a modern crocodile, and the vertebræ of its predecessor from the Trias. This peculiar reptile clearly represents an important stage in the progressive series, and evidently one soon after the separation of the crocodile branch from the main stem. The modern Gavial type appears to have been developed about the same time, as the form was well established in the Upper Cretaceous genus, *Thoracosaurus*. The Teleosaurian group, with biconcave vertebræ,

[1] *See* note on page 520, also section.

evidently the parent stock of Crocodilians, became extinct with *Hyposaurus* of the same horizon, leaving the crocodile and gavial, with their more perfect procœlian vertebræ, to contend for the supremacy. In the early Eocene, both of these types were abundant, but some of the crocodiles possessed characters pointing toward the alligators, which do not appear to have been completely differentiated until later.

Nothing is really known to-day of the earlier genealogy of the *Pterosauria;* but our American forms, without teeth, are clearly the last stage in their development before this peculiar group became extinct. The oldest European form, *Dimorphodon*, from the Lower Lias, had the entire jaws armed with teeth, and was provided with a long tail. The later genus, *Pterodactylus*, retained the teeth, but had essentially lost the tail; while *Ramphorhynchus* had retained the elongated tail, but had lost the teeth from the fore-part of both jaws. In the genus *Pteranodon*, from the American Cretaceous, the teeth are entirely absent, and the tail is a mere rudiment. In the gradual loss of the teeth and tail, these reptiles followed the same path as birds, and might thus seem to approach them, as many have supposed. This resemblance, however, is only a superficial one, as a study of the more important characters of the Pterodactyls shows that they are an aberrant type of reptiles, totally off the line through which the birds were developed. The announcement made not long since in Europe, and accepted by some American authors, that the *Pterosauria*, in consequence of certain points in their structure, were essentially birds, is directly disproved by American specimens, far more perfect than those on which the conclusion was based.

It is now generally admitted, by biologists who have made a study of the vertebrates, that birds have come down to us through the Dinosaurs, and the close affinity of the latter with recent struthious birds will hardly be questioned. The case amounts almost to a demonstration, if we compare, with Dinosaurs, their contemporaries, the Mesozoic birds. The classes of Birds and Reptiles, as now living, are separated by a gulf so profound that a few years since it was cited by the opponents of evolution as the most important break in the animal series, and one which that doctrine could not bridge over. Since then, as Huxley has clearly shown, this gap has been virtually filled by the discovery of bird-like reptiles and reptilian birds. *Compsognathus* and *Archæopteryx* of the Old World, and *Ichthyornis* and *Hesperornis* of the New, are the stepping-stones by which the evolutionist of to-day leads the doubting brother across the shallow remnant of the gulf once thought impassable.

[*To be continued.*]

THE GROWTH OF THE STEAM-ENGINE.[1]

By Professor R. H. THURSTON,
of the Stevens Institute of Technology.

V.

STEAM-NAVIGATION (*continued*).

93. The prize gained by Fulton was, however, most closely contested by Colonel John Stevens, of Hoboken, who has been already mentioned in connection with the early history of railroads, and who had been, since 1791, engaged in similar experiments.

In 1789 he had petitioned the Legislature of the State of New York for an act similar to that granted Livingston, and stated that his plans were complete, and on paper.

In 1804, while Fulton was in Europe, Stevens had completed a steamboat (Fig. 53) sixty-eight feet long and fourteen feet beam, which combined novelties and merits of design in a manner that was

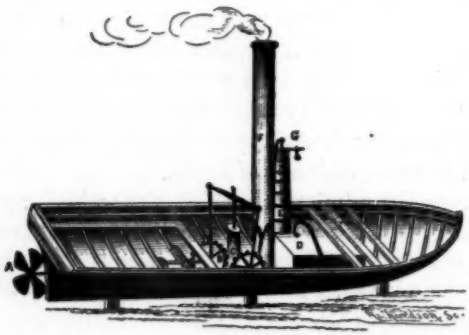

Fig. 53.—John Stevens's Screw-Steamer, 1804.

the best possible evidence of remarkable inventive talent, as well as of the most perfect appreciation of the nature of the problem which he had proposed to himself to solve.

The machinery of this interesting vessel is carefully preserved among the collections of the Stevens Institute of Technology. Its boiler, shown in section, in Fig. 54, is of what is now known as the water tubular variety. The inventor says in his specifications: "The principle of this invention consists of forming a boiler by means of a system or combination of small vessels, instead of using, as is the common mode, one large one; the relative strength of the materials

[1] An abstract of "A History of the Growth of the Steam-Engine," to be published by D. Appleton & Co.

of which these vessels are composed increasing in proportion to the diminution of capacity." The steamboat boiler of 1804 was built to bear a working pressure of over fifty pounds to the square inch, at a time when the usual pressures were from four to seven pounds. It consists of two sets of tubes, closed at one end by solid plugs, and at their opposite extremities screwed into a stayed water and steam reservoir, which was strengthened by hoops. The whole of the lower portion was inclosed in a jacket of iron lined with non-conducting material. The fire was built at one end, in a furnace inclosed in this jacket. The furnace-gases passed among the tubes, down under the body of the boiler, up among the opposite set of tubes, and thence to the smoke-pipe. In another form, as applied to a locomotive in 1825, the tubes were set vertically in a double circle surrounding the fire.

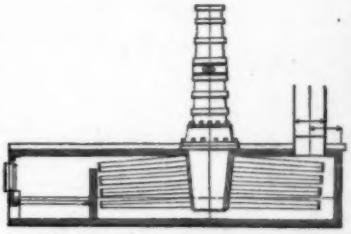

FIG. 54.—STEVENS'S "SECTIONAL" BOILER, 1804.

The engine (Fig. 55) was a direct-acting, high-pressure condensing engine of ten inches diameter of cylinder, two feet stroke of piston, and drove a *screw* of four blades, and of a form which, even to-day, appears quite good. The hub and one blade of this screw are still preserved. The whole is a most remarkable piece of early engineering. The use of such a boiler seventy years ago is even more remarkable than the adoption of the screw-propeller in such excellent proportions thirty years before the labors of Smith and of Ericsson brought the screw into general use. We have, in this strikingly original combination, as good evidence of the existence of unusual engineering talent, in this fellow-countryman of ours, as we found of his political and statesman-like ability in those efforts to forward the introduction of railways already described.

Colonel Stevens designed a peculiar form of iron-clad in the year 1812, which has been since reproduced by no less distinguished and successful an engineer than the late John Elder, of Glasgow, Scotland. It consisted of a saucer-shaped hull, carrying a heavy battery and plated with iron of ample thickness to resist the shot fired from the heaviest ordnance then known. This vessel was secured to a swivel, and was anchored in the channel to be defended. A set of screw-propellers driven by steam-engines and situated beneath the vessel, where they were safe against injury by shot, were so arranged as to permit the vessel to be rapidly revolved about its centre. As each gun was brought into line of fire it was discharged, and was then reloaded before coming around again. This was probably the earliest embodiment of the now well-established "Monitor" principle.

This great engineer and inventor was therefore far in advance of

his time. The sectional steam-boiler only just becoming a standard type; high-pressure steam with condensation has just become generally adopted; the screw only came in use forty years later, when Ericsson, Smith, and Woodcroft, came forward with it, and twin-

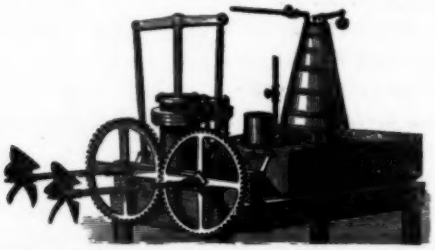

FIG. 55.—MACHINERY OF TWIN-SCREW STEAMER OF 1804.

screws are hardly yet familiar to engineers. The revolving battery protected by iron plating is another of what are generally considered recent devices; and the peculiar Stevens revolving ship is reproduced by Elder sixty years later.

A model of the little steamer built in 1804 is preserved in the lecture-room of the department of mechanical engineering at the Stevens Institute of Technology, and the machinery itself (Fig. 55), the high-pressure "section" or "safety" tubular boiler as it would be called to-day, the high-pressure condensing engine with rotating valves, and with twin-screw propellers, is given a place of honor in the model-room or museum, where it contrasts singularly with the mechanism contributed to the collection by manufacturers and inventors of our own time.

94. The first of Stevens's boats performed so well that he immedi-

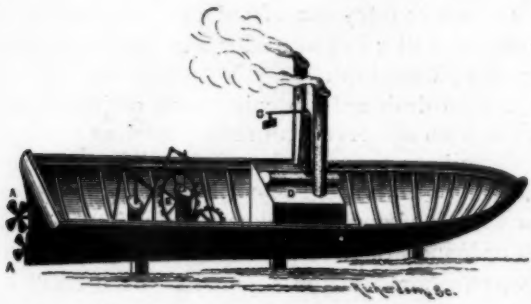

FIG. 56.—STEVENS'S TWIN-SCREWS, 1806.

ately built another one, using the same engine as before, but employing a larger boiler, and propelling the vessel by *twin-screws* (Fig. 56 [1]), the latter being another instance of his use of a device brought forward long afterward as new, and since frequently adopted.

[1] These cuts are *fac-similes* of steel engravings made for Stevens.

This boat was sufficiently successful to indicate the probability of making steam-navigation a commercial success, and Stevens, assisted by his sons, built a boat which he named the Phœnix, and made the first trial in 1807, just too late to anticipate Fulton. This boat was driven by paddle-wheels.

The Phœnix, shut out of the waters of the State of New York by the monopoly held by Fulton and Livingston, was placed for a time on a route between Hoboken and New Brunswick; and then, anticipating a better pecuniary return, it was concluded to send her to Philadelphia to ply on the Delaware.

At that time, no canal offered the opportunity to make an inland passage, and, in June, 1808, Robert L. Stevens, a son of John, started with Captain Bunker to make the passage by sea.

Although meeting a gale of wind, he arrived at Philadelphia safely, having been the first to trust himself on the open sea in a vessel relying entirely upon steam-power.

95. From this time forward the Messrs. Stevens, father and sons, continued to construct steam-vessels.

Robert L. Stevens.

After Fulton and Stevens had led the way, steam-navigation was introduced very rapidly on both sides the ocean, and on the Mississippi the number of boats set afloat was soon large enough to fulfill Evans's prediction that the navigation of that river would become a steam-navigation.

Except in Stevens's earlier boats, and in the boats plying on the

Western rivers, all steamers were then propelled, as they are still, by condensing engines. The instrument of propulsion was also, even in Stevens's own boats after his earlier experiments, the paddle-wheel. The use of the screw did not become general, even in deep water, until within the last twenty years.

96. The steam-engine in most general use for sea-going ships when the introduction of the screw compelled its withdrawal, with the paddle-wheel which it drove, was that shown in Fig. 57, which represents the side-lever engine of the steamer Pacific, as designed by Charles W. Copeland.

In the sketch, *A* is the steam-cylinder; *B C* the side-rods, or links, connecting the cross-head in the piston-rod with the end-centres

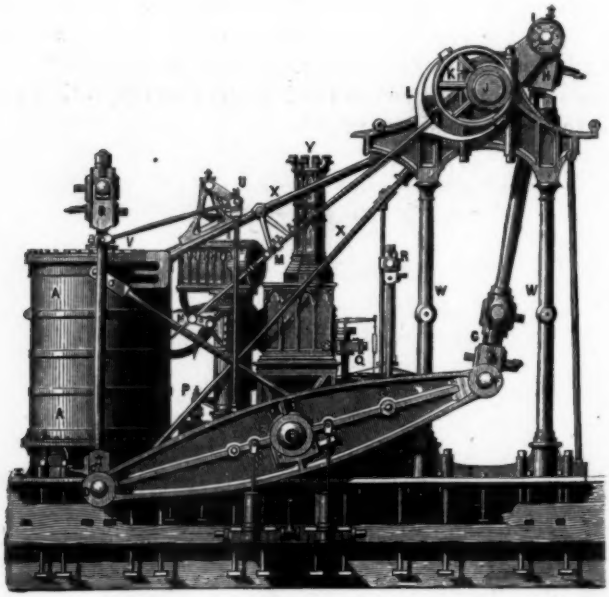

Fig. 57.—The Side-Lever Engine, 1849.

D, of the side-lever *D E F*, which vibrates about the main centre *E*, like the overhead beams. A cross-tail at *G* is connected with the side-lever and with the connecting-rod *G H*, which latter communicates motion to the crank *I J*, turning the main shaft *J*. The air-pump and condenser are seen at *O M*. This engine was one of the earliest and best examples of the type, and perhaps the first ever fitted with a framing of wrought-iron.

97. After the experiments of Stevens, we find no evidence of the use of the screw, although schemes were proposed and various forms were even patented, until about 1836.

In 1836 Francis P. Smith, an English farmer, who had become

interested in the subject, experimented with a screw made of wood, and fitted in a boat built with funds furnished by a Mr. Wright, a London banker. He exhibited it on the Thames and on the Paddington Canal for several months. In February, 1837, by an accident, a part of the screw-blade was broken off, and the improved performance of the boat called attention to the advisability of determining its best proportions.

FIG. 58.—THE SIDE-WHEEL OCEAN-STEAMER, 1850.

In 1837 Smith exhibited his courage and his faith in the reliability of his little steamer by making a coasting-voyage in quite heavy weather, and the performance of his vessel was such as to fully justify the confidence felt in it by its designer.

The British Admiralty soon had its attention called to the performance of this vessel, and to the very excellent results attained by the Archimedes, a vessel of 237 tons burden, which was built by Smith and his coadjutors in 1838, and tried in 1839, attaining a speed of eight knots an hour. By the performance of the Archimedes, the advantages of screw-propulsion, especially for naval purposes, were rendered so evident that the British Government built its first screw-vessel, the Rattler, and Brunel adopted the screw in the iron steamer Great Britain, which had been designed originally as a paddle-steamer.

98. Simultaneously with Smith, Captain John Ericsson was engaged in the same project.

He patented, July, 1836, a propeller which was found at the first trial to be of such good form and proportions as to give excellent results.

His first vessel was the Francis B. Ogden, named after the United States consul at Liverpool, who had lent the inventor valuable aid in his work. The boat was forty-five feet long, eight feet beam, and drew

three feet of water. It attained a speed of ten miles an hour, and towed an American packet-ship, the Toronto, four and a half miles an hour on the Thames. This was a splendid success.

Ericsson built several screw-boats, and finally, meeting Captain Robert F. Stockton, of the United States Navy, that gentleman was so fully convinced of the merits of Ericsson's plans that he ordered an iron vessel of seventy feet length and ten feet beam, with engines of fifty-horse power.

The trial of the Stockton, in 1839, was eminently satisfactory. The vessel was sent to America under sail, and the designer was soon induced to follow her to this country, where his later achievements are well known.

The engines of the Stockton were direct-acting, the first examples of engines coupled directly to the crank-shaft without intermediate gearing, that we meet with after that of John Stevens.

99. Soon after Ericsson arrived in the United States, he obtained an opportunity to design a screw-steamer for the United States Navy, the Princeton, and, at about the same time, the English and French Governments had screw-steamers built from his plans, or from those of his agent in England, the Count de Posen.

In these ships—the Amphion and the Pomone—the first horizontal, direct-acting engines ever built were used. They were fitted with double-acting air-pumps, having canvas valves and other novel features.

From 1840 the screw gained favor rapidly, and finally began to displace the paddle for deep-water navigation. Progress in this direction was at first somewhat slow.

In 1840, and during the following ten years, many experiments were instituted between the performance of screw and paddle steamers without definitely settling engineering practice.

100. The reason was, probably, that the introduction of the rapidly-revolving screw, in place of the slow-moving paddle-wheel, necessitated a complete revolution in the design of their steam-engines. And the unavoidable change from the heavy, long-stroked, low-speed engines, previously in use, to the light engines, with small cylinders and high piston-speed, called for by the new system of propulsion, was one that necessarily occurred slowly, and was accompanied by its share of those engineering blunders and accidents that invariably take place during such periods of transition.

Engineers had first to learn to design such engines as should be reliable under the then novel conditions of screw-propulsion, and their experience could only be gained through the occurrence of many mishaps and costly failures. The best proportions of engines and screws for a given ship were determined only by long experience, although great assistance was derived from the extensive series of experiments made on the French steamer Pelican. It also became

necessary to train up a body of engine-drivers who should be capable of managing these new engines, for they required the exercise of a then unprecedented amount of care and skill. Finally, with the accomplishment of these two requisites to success, must simultaneously occur the enlightenment of the public, professional as well as non-professional, in regard to their advantages.

Thus it happens that it is only very recently that the screw has

FIG. 80.—THE MODERN STEAMSHIP: THE GERMANIC.

attained its proper place as an instrument of propulsion, and has only now driven the paddle-wheel almost out of use, except in shoal water.

Now our large screw-steamers are of higher speed than any paddle-steamers on the ocean, sometimes crossing the Atlantic from New

York to Queenstown in a week, making their passages with wonderful regularity, and developing their power at far less cost than the old side-wheel steamers. This increased economy is due, not only to the use of a more efficient propelling instrument, but, perhaps in even a higher degree, to the economy which has followed as a consequence of the accompanying changes in structure of the steam-engine driving it.

101. The earliest days of screw propulsion witnessed the use of steam of ten or fifteen pounds' pressure, in a geared engine using jet condensation, and giving a horse-power at an expense of, perhaps, seven or eight pounds of coal per hour.

A little later came direct-acting engines with jet condensation, and steam at twenty pounds' pressure, costing about five or six pounds per horse-power per hour. The steam-pressure rose a little higher with the use of greater expansion, and the economy of fuel was further increased. The introduction of the surface-condenser, which began to be generally adopted some ten or fifteen years ago, brought down the cost of power to between three and four pounds in the better class of engines.

At about the same time, this change to surface-condensation helping greatly to overcome the troubles arising from boiler-incrustation, which had checked the rise in steam-pressure above about twenty-five pounds, and, it being at the same time learned by engineers that the deposit of the scale and sulphate of lime in the marine boiler was determined by temperature rather than by the degree of concentration, and that all the lime entering the boiler was deposited at the pressure just mentioned, a sudden advance took place.

Careful design, good workmanship, and skillful management, made the surface-condenser an efficient apparatus, and, the dangers of incrustation being thus lessened, the movement toward higher pressures recommenced and progressed so rapidly that, now, seventy-five pounds per square inch is very usual, and two hundred and fifty pounds has been attained in marine engines built by the Messrs. Perkins, who are said to have reached the remarkable economy of a horse-power for each pound of combustible consumed in the boiler.

102. These high pressures, and the greater expansion of the steam, have, in turn, produced another revolution in engine-construction.

It has at last become generally known, as was seen by well-informed and scientific engineers long ago, that one of the most serious losses of heat, and consequently of power, in the steam-engine, when expansion is carried to a considerable extent, occurs in consequence of condensation and the deposition of moisture upon the interior of the cylinder, which moisture, when the exhaust takes place, carries, by its reëvaporation, large quantities of heat into the condenser, without deriving any power from it.

The steam-jacket furnishes one means of reducing the amount of

this loss by keeping up the temperature of the interior of the cylinder, and thus preventing, in some degree, this deposition, and by reëvaporating this moisture during expansion, and thus deriving useful effect from heat so expended before the exhaust-valve opens, and it is thrown unutilized into the condenser.

James Watt, therefore, applied the steam-jacket more wisely than he knew, for this matter was not, in his time, understood. Indeed, he gave up its use, thinking it could have no possible economical value, but the consequent falling off in the duty of the engine induced him to restore it, and we still find it on the Cornish engine of to-day.

103. This loss is also, in some degree, prevented, by dividing the expansive working of the steam among two or more cylinders, as in the compound or Woolf system described in the preceding lectures.

Here the heat wasted in either cylinder is less, in consequence of the lessened range of temperature, and that lost by one cylinder is carried into the second, and then, to some extent, utilized.

The amount of saving effected by these means is quite considerable—so great, in fact, as to have produced a complete revolution in engineering practice in the construction of marine engines by the best-known builders.

JOHN ELDER.

They have, under the lead of John Elder, adopted the Woolf engine, which had, in earlier times, with lower steam, less expansion, and less intelligent engineering, proved apparently a failure.

104. To-day, nearly all sea-going steamers are fitted with such

engines having surface-condensers, and with tubular boilers, which are fitted, frequently, with superheaters. One of the best examples of these steamers, the City of Peking, a screw-steamer built by Roach

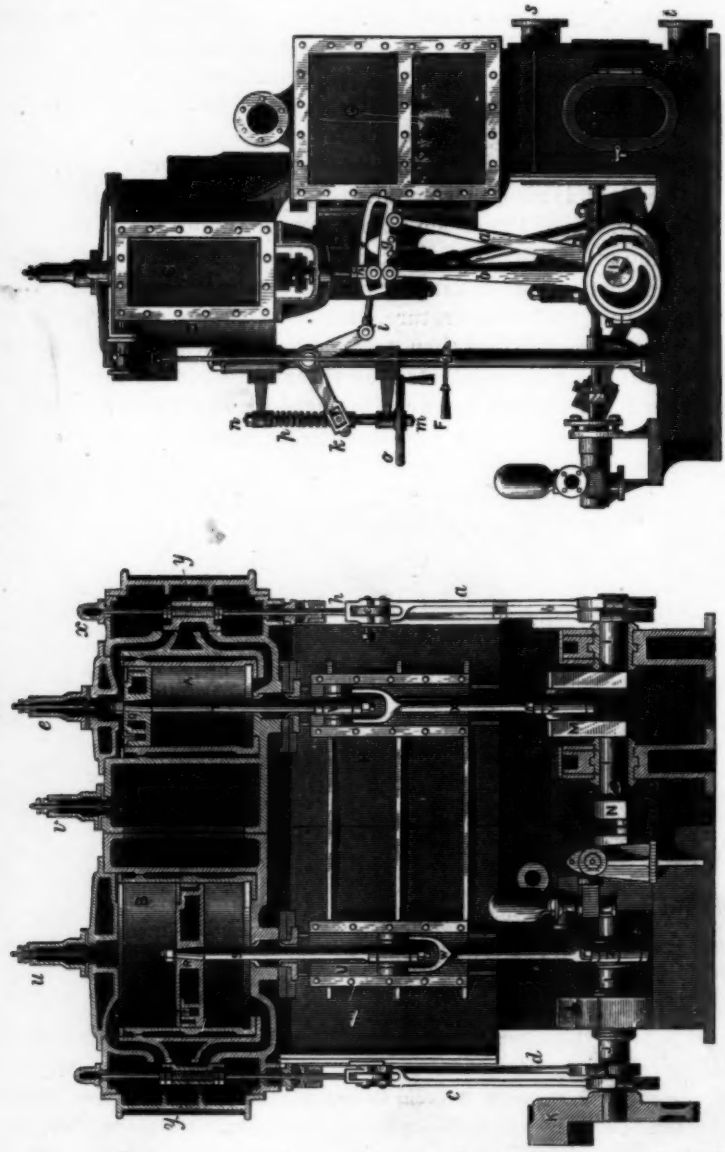

FIG. 60.—THE MODERN COMPOUND MARINE STEAM-ENGINE.

for the Pacific Mail Company, is a vessel of 5,000 tons. There are two pairs of compound-engines, having cylinders of 51 and 88 inches diameter, and 4½ feet stroke of piston. The crank-shafts are 18 inches in

diameter. Steam is carried at 60 pounds, and is expanded nine times. The boilers are ten in number, cylindrical in form, and with cylindrical flues; they are 13 feet in diameter, 10½ feet long, with shells of iron $\frac{13}{16}$ inch thick, and have 520 feet of grate-surface, 16,500 square feet of heating-surface, and 1,600 square feet of superheating-surface. The smoke-funnels, or stacks, are 8½ feet in diameter and 70 feet high.

Fig. 60 shows a section of the simplest and the least costly form of compound-engine, as it is now built on the Clyde, in Great Britain, and in the United States, on the Delaware.

Here, the cranks *Y Z* are coupled at an angle of ninety degrees, only two cylinders, *A B*, being used, and an awkward distribution of pressure is avoided by having a considerable volume of steam-pipe, or by a steam-reservoir, *O P*, between the two cylinders.

The valves, *y y*, are set like those of an ordinary engine, the peculiarity being that the steam exhausted by the one cylinder, *A*, is used again in the second and larger one, *B*. In this combination, the expansion is generally carried to about six times, the pressure of steam in the boiler being usually between sixty and seventy-five pounds per square inch.

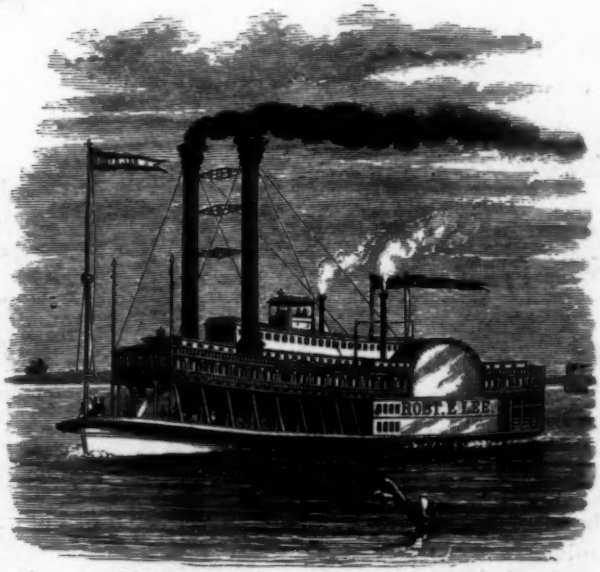

FIG. 61.—THE MISSISSIPPI STEAMBOAT, 1876.

105. The revolution by which the screw has superseded the paddle-wheel elsewhere, has not taken place in our shallow American rivers, where there is not depth enough for the screw.

In the West, boats are driven by the horizontal high-pressure engine usually, as in the days of Oliver Evans, and retain their peculiarities of construction. Some of the Mississippi steamboats (Fig. 61)

make the trip from St. Louis to New Orleans—about 1,200 miles—in four days, and can make, in still water, more than twenty miles an hour.

In the East, we have a form of engine which is distinctively known as the American steamboat-engine. It is shown in Fig. 62.

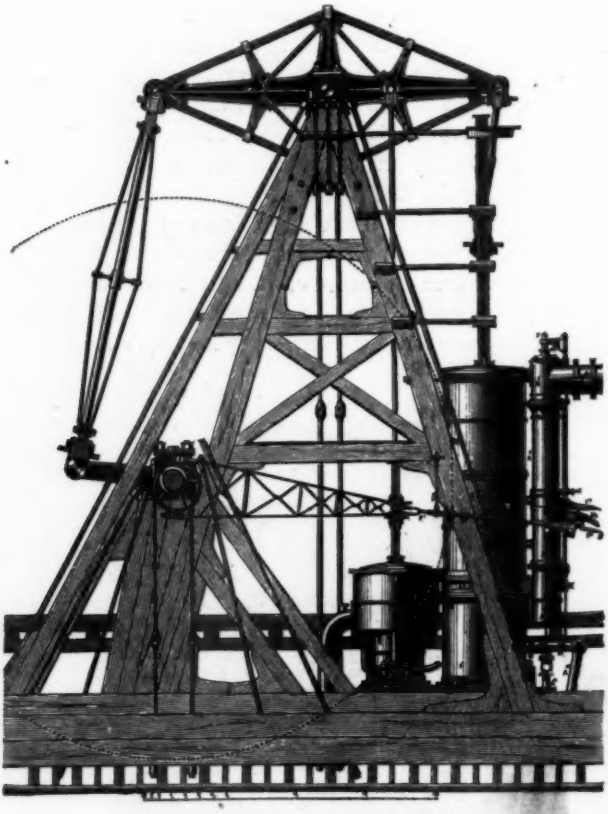

FIG. 62.—THE AMERICAN BEAM-ENGINE.

This engine is recognized throughout the engineering world as one of the most complete and thoroughly perfected of known *types* of steam-engine.

106. This peculiarly effective and easy-working engine, and the equally peculiar vessel (Fig. 63) which is usually impelled by it, are, in all their peculiarities, characteristically American.

The "skeleton-beam," which is one of the prominent features, was first used by Robert L. Stevens on the ferry-boat Hoboken, in 1822.

The valve-gear is usually that known as the "Stevens valve-gear." It was invented by Messrs. Robert L. and Francis B. Stevens, in 1841. The "gallows-frame" took its present form in the hands of

Messrs. Stevens. The hull of the Phœnix had hollow water-lines sixty-five years ago, and this important characteristic of modern vessels is, therefore, an American improvement.

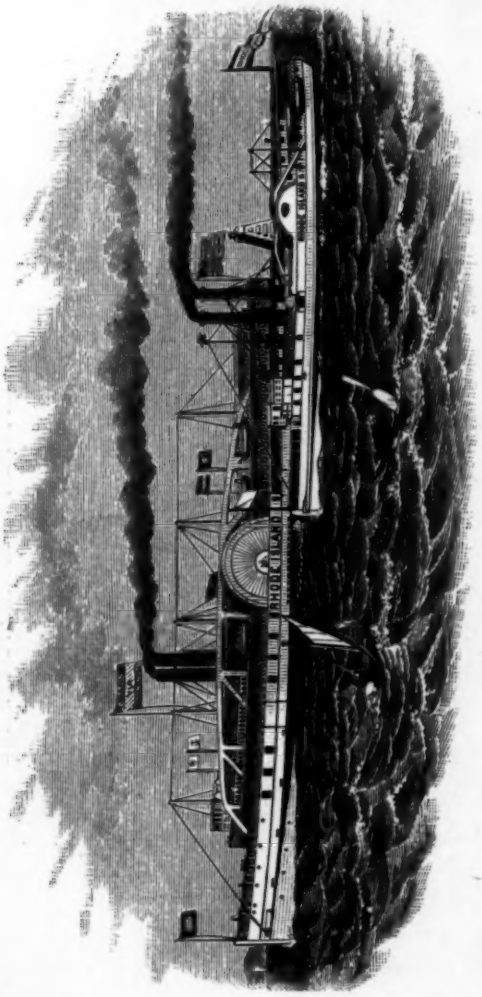

FIG. 63.—THE TWO RHODE ISLANDS, 1826-1876.

The North America (Fig. 64) was built in 1827. The hull was stiffened by the "hog-frame," now as distinctive a characteristic of the vessel as are the gallows-frame and the skeleton-beam of the engine.

This engine is not usually quite as economical in fuel as are the screw-engines last described; but it has the advantages—which are so extremely important in the shallow, flexible hulls of our river-boats

—of being the easiest working and least easily injured, by "getting out of line," of all known forms of engines.

The British and Continental engineers also still retain the paddle-wheel in some of the steamers plying in their narrower and more

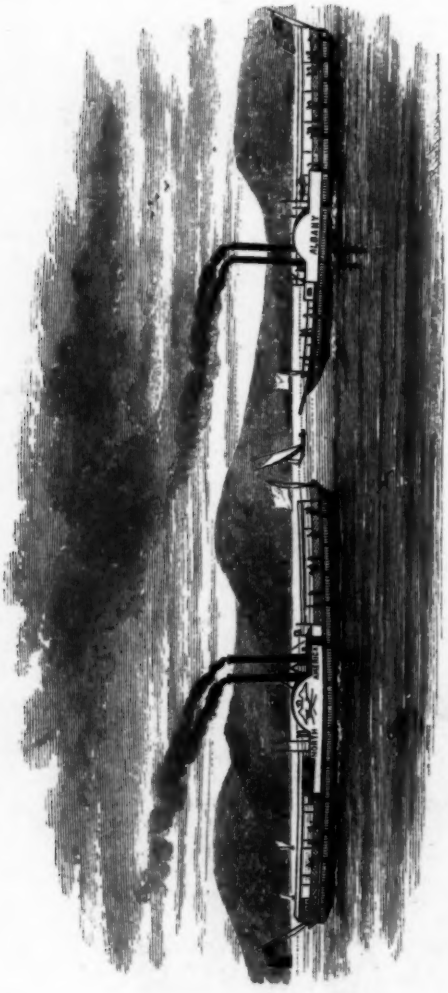

FIG. 64.—THE NORTH AMERICA AND THE ALBANY, 1837.

closely-crowded rivers and harbors, in consequence of the greater facility which it gives for manœuvring.

107. The magnitude of our modern steamships excites the wonder and admiration of even the people of our own time. There is certainly no creation of art that can be grander in appearance than a transatlantic steamer, a hundred and fifty yards in length, and weighing,

with her stores, 5,000 or 6,000 tons, as she starts on her voyage, moved by engines more than equal in power to the united strength of 5,000 horses. Nothing can more thoroughly awaken a feeling of awe than the sight of immense structures like the great modern iron-clads (Fig. 65), vessels having a total weight of 8,000 to 10,000 tons,

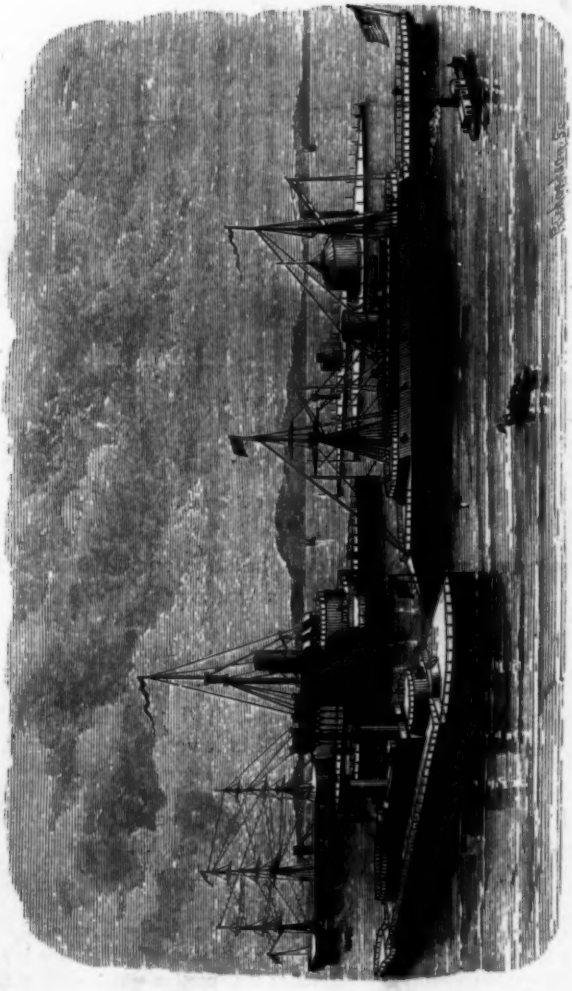

FIG. 65.—MODERN IRON-CLADS.

and propelled by steam-engines of 8,000 or 10,000 horse-power, carrying guns whose shot penetrate solid iron fifteen inches thick, and having a power of impact, when steaming moderately, sufficient to raise 35,000 tons a foot high.

108. Far more huge than the Monarch among the iron-clads even is that prematurely-built monster, the Great Eastern (Fig. 66), more

than the eighth of a mile (680 feet) long, of 84 feet beam, and drawing thirty feet of water at load-draught, when the weight of ship and contents amounts to over 25,000 tons. This great vessel

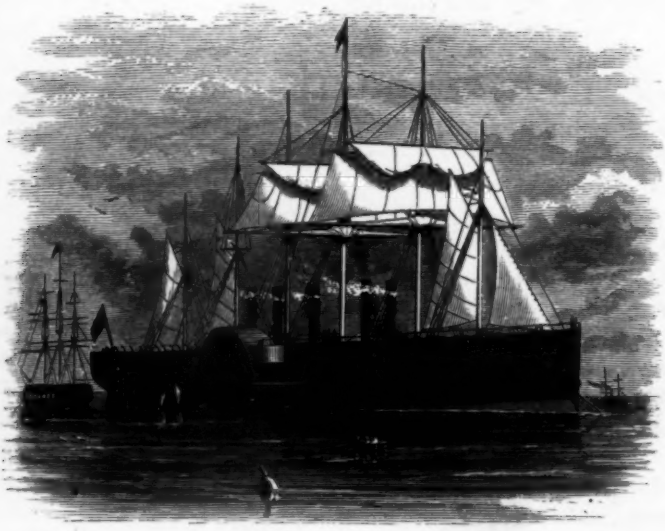

FIG. 66.—THE GREAT EASTERN.

is driven by steam-engines of 10,000 horse-power, turning huge paddle-wheels 56 feet in diameter, and a screw-propeller having a diameter of 24 feet.

109. We are evidently fulfilling at least a part of that well-known poetical prophecy which Darwin wrote in the early days of the steam-engine, and possibly before Watt had told him of the great advance which had been produced by his inventive genius:

> "Soon shall thy arm, unconquered steam, afar
> Drag the slow barge, or drive the rapid car;
> Or, on wide-waving wings expanded, bear
> The flying chariot through the fields of air."

NOTE.—We are compelled to omit the sketch of the development of the stationary engine, and for it must refer our readers to the publication of which this is an abstract. We shall conclude this series by an abstract of that portion which outlines the Philosophy of the Steam-Engine, and exhibits the direction of improvement, and the changes which must precede the production of a possible new type, "the steam-engine of the future."

[1] "Botanic Garden," London, 1781.

EVOLUTION OF CEREMONIAL GOVERNMENT.

By HERBERT SPENCER.

II. TROPHIES.

EFFICIENCY of every kind is a source of self-satisfaction; and proofs of it are prized as bringing applause. The sportsman, narrating his successes when opportunity serves, keeps such spoils of the chase as he conveniently can. Is he a fisherman? Then, occasionally, the notches cut on the butt of his rod show the number and lengths of his salmon; or, in a glass case, there is preserved the great Thames-trout he once caught. Has he stalked deer? Then in his hall, or dining-room, are fixed up their heads; which he greatly esteems when the attached horns have many "points." Still more, if he is a successful hunter of tigers, does he value the skins demonstrating his prowess.

Trophies of such kinds, even among ourselves, give to their owner some influence over those around him. A traveler who has brought from Africa a pair of elephant's tusks, or the formidable horn of a rhinoceros, impresses those who come in contact with him as a man of courage and resource, and, therefore, as one not to be trifled with. A vague kind of governing power accrues to him.

Naturally, by primitive men, whose lives are predatory, and whose respective values largely depend on their powers as hunters, animal-trophies are still more prized, and tend, in a greater degree, to bring honor and influence. Hence the fact that rank in Vate is indicated by the number of bones of all kinds suspended in the house. Of the Shoshone warrior we are told that, "killing a grizzly bear also entitles him to this honor, for it is considered a great feat to slay one of these formidable animals, and only he who has performed it is allowed to wear their highest insignia of glory, the feet or claws of the victim." Among the Santals "it is customary to hand these trophies (skulls of beasts, etc.) down from father to son." And when, with such facts to give us the clews, we read that the habitation of the king of the Koossas "is no otherwise distinguished than by the tail of a lion or a panther hanging from the top of the roof," we can scarcely doubt that this symbol of royalty was originally a trophy displayed by a chief whose prowess had gained him supremacy.

But, as, among the uncivilized and semi-civilized, human enemies are more to be feared than beast enemies, and conquests over men are therefore occasions of greater triumphs than conquests over animals, it results that proofs of such conquests are usually still more valued. A brave who returns from battle does not get honor if his boasts are unsupported by evidence; but if he proves that he has killed his man

by bringing back some part of him—especially a part which the corpse could not yield in duplicate—he raises his character in the tribe and increases his power. Preservation of trophies, with a view to display and consequent strengthening of personal influence, therefore becomes an established custom. In Ashantee "the smaller joints, bones, and teeth of the slain are worn by the victors about their persons." Among the Ceris and Opatas of North Mexico, "many cook and eat the flesh of their captives, reserving the bones as trophies." And another Mexican race, "the Chichimecs, carried with them a bone on which, when they killed an enemy, they marked a notch, as a record of the number each had slain." The meaning of trophy-taking, and its social effects, being recognized, let us consider in groups the various forms of it.

Of parts cut from the bodies of the slain, heads are the commonest; probably as being the most unmistakable proofs of victory.

We need not go far afield for illustrations both of the practice and its motives. The most familiar of books contains them. In Judges vii. 25, we read: "And they took two princes of the Midianites, Oreb and Zeeb; and they slew Oreb upon the rock Oreb, and Zeeb they slew at the wine-press of Zeeb, and pursued Midian, and brought the heads of Oreb and Zeeb to Gideon on the other side Jordan." The decapitation of Goliath by David, followed by carrying of his head to Jerusalem, further illustrates the custom. And, if, by so superior a race, heads were taken home as trophies, we shall not wonder at finding the custom of so taking them among inferior races all over the globe. By the Chichimecs in North America "the heads of the slain were placed on poles and paraded through their villages in token of victory, the inhabitants meanwhile dancing round them." In South America, by the Abipones, heads are brought back from battle "tied to their saddles;" and the Mundrucus "ornament their rude and miserable cabanas with these horrible trophies." Of Malayo-Polynesians having a like habit, may be named the New-Zealanders; they dry and treasure up the heads of their slain foes. In Madagascar, during Queen Ranavalona's reign, heads raised on poles were placed along the coast. Skulls of enemies are preserved as trophies by the natives on the Congo, and by other African peoples: "The skull and thigh-bones of the last monarch of Dinkira are still trophies of the court of Ashantee." Among the Hill-tribes of India, the Kukis may be instanced as having this practice. Morier tells us that in Persia, under the stimulus of money-payments, "prisoners" (of war) "have been put to death in cold blood, in order that the heads, which are immediately dispatched to the king and deposited in heaps at the palace-gate, might make a more considerable show." And that among other Asiatic races head-taking persists spite of semi-civilization, we are reminded by the recent doings of the Turks, who have in some cases exhumed the bodies of slain foes and decapitated them.

This last instance draws attention to the fact that this barbarous custom has been, and is, carried to the greatest extremes, along with militancy the most excessive. Among ancient examples there are the doings of Timour, with his exaction of 90,000 heads from Bagdad. Of modern examples the most notable comes from Dahomey. "The sleeping-apartment of a Dahoman king," says Burton, "was paved with the skulls of neighboring princes and chiefs, placed there that the king might tread upon them." And, according to Dalzel, the king's statement, that "his house wanted thatch," was "used in giving orders to his generals to make war, and alludes to the custom of placing the heads of the enemy killed in battle, or those of the prisoners of distinction, on the roofs of the guard-houses at the gates of his palaces."

But now, ending instances, let us observe how this taking of heads as trophies initiates a means of strengthening political power; how it becomes a factor in sacrificial ceremonies; and how it enters into social intercourse as a controlling influence. That the pyramids and towers of heads built by Timour at Bagdad and Aleppo, must have conduced to his supremacy by striking terror into the subjugated, as well as by exciting dread of vengeance for insubordination among his followers, cannot be doubted; and that living in a dwelling paved and decorated with skulls, implies, in a Dahoman king, a character generating fear among enemies and obedience among subjects, is obvious. In Northern Celebes, where, before 1822, "human skulls were the great ornaments of the chiefs' houses," these proofs of victory in battle, used as symbols of authority, could not fail to exercise a governmental effect.

That heads are offered in propitiation of the dead, and that the ceremony of offering them is thus made part of a quasi-worship, there are clear proofs. One is supplied by the people just named. "When a chief died his tomb must be adorned with two fresh human heads, and if those of enemies could not be obtained slaves were killed for the occasion." Among the Dyaks, who, though in many respects advanced, have retained this barbarous practice sanctified by tradition, it is the same: "the aged warrior could not rest in his grave till his relatives had taken a head in his name." By the Kukis of Northern India sacrificial head-taking is carried still further. Making raids into the plains to procure heads, they "have been known in one night to carry off fifty. These are used in certain ceremonies performed at the funerals of the chiefs, and it is always after the death of one of their rajahs that these incursions occur."

That the possession of these grisly tokens of success gives an influence in social intercourse, proof is yielded by the following passage from St. John: "Head-hunting is not so much a religious ceremony among the Pakatans, Borneo, as merely to show their bravery and manliness. When they quarrel, it is a constant phrase,

'How many heads did your father or grandfather get?' If less than his own number, 'Well, then, you have no occasion to be proud.' "

The head of an enemy is of inconvenient bulk; and when the journey home is long there arises a question—cannot proof that an enemy has been killed be given by carrying back a part only? In some places the savage infers that it can, and acts on the inference.

This modification and its meaning are well shown in Ashantee, where "the general in command sends to the capital the jawbones of the slain enemies;" and where, as Ramseyer further tells us, "a day of rejoicing occurred on July 3d, when nineteen loads of jaws arrived from the seat of war as trophies of victory." When first found, the Tahitians, too, carried away the jawbones of their enemies; and Cook saw fifteen of them fastened up at the end of a house. Similarly of Vate, where "the greater the chief, the greater the display of bones," we read that, if a slain enemy was "one who spoke ill of the chief, his jaws are hung up in the chief's house as a trophy:" a tacit threat to others who vilified him. A recent account of another Papuan race inhabiting Boigu, on the coast of New Guinea, further illustrates the practice, and also its social effect. Mr. Stone writes: "By nature these people are bloody and warlike among themselves, frequently making raids to the 'Big Land,' and returning in triumph with the heads and jawbones of their slaughtered victims, the latter becoming the property of the murderer, and the former of him who decapitates the body. The jawbone is consequently held as the most valued trophy, and the more a man possesses the greater he becomes in the eyes of his fellow-men." It may be added that, by the Tupis of South America, trophies of an allied kind were worn. In honoring a victorious warrior, "among some tribes they rubbed his pulse with one of the eyes of the dead, and hung the mouth upon his arm like a bracelet."

With the display of jaws as trophies, there may be named a kindred use of teeth. America furnishes instances. The Caribs "strung together the teeth of such of their enemies as they had slain in battle, and wore them on their legs and arms." The Tupis, after devouring a captive, preserved "the teeth strung in necklaces." The Moxos women wore "a necklace made of the teeth of enemies killed by their husbands in battle." In the times of the Spanish invaders, the Central Americans made an image, "and in its mouth were inserted teeth taken from the Spaniards whom they had killed." And a passage quoted above specifies teeth as among the trophies worn by the Ashantees.

Other parts of the head, easily detached and carried, also serve. Where many enemies are slain, the collected ears yield in small bulk a means of counting; and probably Zenghis Khan had this end in view when, in Poland, he "filled nine sacks with the right ears of the

slain." Noses, again, are in some cases chosen as easily-enumerated trophies. Anciently, by Constantine V., "a plate of noses was accepted as a grateful offering;" and, at the present time, the noses they have taken are carried by soldiers to their leaders in Montenegro. That the slain Turks thus deprived of their noses, even to the extent of 500 on one battle-field, were so treated in retaliation for the decapitations the Turks had been guilty of, is true; but this excuse does not alter the fact that "the Montenegrin chiefs could not be persuaded to give up the practice of paying their clansmen for the number of noses produced."

The ancient Mexicans, having for gods their deified cannibal ancestors, in whose worship the most horrible rites were daily performed, in some cases took as trophies the entire skins of the vanquished. "The first prisoner made in a war was flayed alive. The soldier who had captured him dressed himself in his bleeding skin, and thus, for some days, served the god of battles. . . . He who was dressed in the skin walked from one temple to another; men and women followed him, shouting for joy." While we here see that the trophy was taken by the victor primarily as a proof of his prowess, we are also shown how there resulted a religious ceremony: the trophy was displayed for the supposed gratification of deities delighting in bloodshed. There is further evidence that this was the intention. "At the festival of the goldsmiths' god Totec, one of the priests put on the skin of a captive, and, being so dressed, he was the image of that god Totec." Nebel (plate 3, Fig. 1) gives the basalt figure of a priest (or idol) clothed in a human skin; and additional evidence is yielded by the custom of the neighboring state of Yucatan, where "the bodies were thrown down the steps, flayed, the priest put on the skins, and danced, and the body was buried in the yard of the temple. They took prisoners in war for these sacrifices, and condemned some of their own people to them."

Usually, however, the skin-trophy is relatively small: the requirement being simply that it shall be one of which the body yields no duplicate. The origin of it is well shown by the following description of a practice among the Abipones. They preserve the heads of enemies, and—

> "When apprehension of approaching hostilities obliges them to remove to places of greater security, they strip the heads of the skin, cutting it from ear to ear beneath the nose, and dexterously pulling it off along with the hair. . . . That Abipon who has most of these skins at home excels the rest in military renown."

Evidently, however, the whole skin is not needful to prove previous possession of a head: the part covering the crown of the head, distinguished from other parts by the arrangement of its hairs, serves the purpose: hence scalping. Tales of Indian life have so far familiar-

ized us with this custom that illustrations are needless. How in some cases, after a victory, "scalps are fixed on a pole" and danced round —how they are "highly prized as trophies, and publicly exhibited at feasts," need not be proved in detail. But one piece of evidence, supplied by the Shoshones, may be named; because it clearly shows us the use of the trophy as an accepted evidence of victory—a kind of legal proof regarded as alone conclusive. We read that—

"Taking an enemy's scalp is an honor quite independent of the act of vanquishing him. To kill your adversary is of no importance unless the scalp is brought from the field of battle; and were a warrior to slay any number of his enemies in action, and others were to obtain the scalps or first touch the dead, they would have all the honors, since they have borne off the trophy."

Though we usually think of scalp-taking in connection with the North American Indians, yet it is not restricted to them. Herodotus describes the Scythians as scalping their conquered enemies; and at the present time the Nagas of the Indian hills take scalps and preserve them.

Preservation of hair alone, as a trophy, is less general; doubtless because the evidence of victory which it yields is inconclusive; one head might supply hair for two trophies. Still there are cases in which an enemy's hair is displayed in proof of success in war. Speaking of a Naga, Grange says his shield "was covered over with the hair of the foes he had killed." The tunic of a Mandan chief is described by Catlin as "fringed with locks of hair taken by his own hand from the heads of his enemies." And we are told of the Cochimis that "at certain festivals their sorcerers . . . . wore long robes of skins, ornamented with human hair."

Among easily-transported parts carried home to prove victory, may next be named hands and feet. By the Mexican tribes, Ceris and Opatas, "the slain are scalped, or a hand is cut off, and a dance performed round the trophies on the field of battle." So, too, of the Californian Indians, who also took scalps, we are told that "the yet more barbarous habit of cutting off the hands, feet, or head, of a fallen enemy, as trophies of victory, prevailed more widely. They also plucked out and carefully preserved the eyes of the slain." Though this is not said, we may assume that either the right or the left foot or hand was the trophy; since, in the absence of any distinction, victory over two enemies instead of one might be alleged. Hands were trophies among ancient peoples of the Old World also. The inscription on a tomb at El Kab in Upper Egypt tells how Aahmes, the son of Abuna, the chief of the steersmen, "when he had won a hand" (in battle), "he received the king's commendation, and the golden necklace in token of his bravery;" and a wall-painting in the temple of Medinet Abou, at Thebes, shows the presentation of a heap of hands to the king.

This last instance introduces us to yet another kind of trophy. Along with the heap of hands thus laid before the king, there is represented a phallic heap; and an accompanying inscription, narrating the victory of Meneptah I. over the Libyans, besides mentioning the "cut hands of all their auxiliaries," as being carried on donkeys following the returning army, mentions these other trophies as taken from men of the Libyan nation. And here a natural transition brings us to trophies of an allied kind, the taking of which, once common, has continued in the neighborhood of Egypt down to modern times. The great significance of the account Bruce gives of a practice among the Abyssinians must be my excuse for quoting part of it. He says:

> "At the end of a day of battle, each chief is obliged to sit at the door of his tent, and each of his followers, who has slain a man, presents himself in his turn, armed as in fight, with the bloody foreskin of the man he has slain. . . . If he has killed more than one man, so many more times he returns. . . . After this ceremony is over, each man takes his bloody conquest, and retires to prepare it in the same manner the Indians do their scalps. . . . The whole army . . . on a particular day of review, throws them before the king, and leaves them at the gate of the palace."

Here it is noteworthy that the trophy, first serving to demonstrate a victory gained by the individual warrior, is subsequently made an offering to the ruler, and further becomes a means of recording the number slain—facts verified by the more recent French traveler d'Hericourt. That like purposes were similarly served among the Hebrews, proof is yielded by the passage which narrates Saul's endeavor to betray David when offering him Michal to wife: "And Saul said, Thus shall ye say to David, The king desireth not any dowry, but an hundred foreskins of the Philistines, to be avenged of the king's enemies;" and David "slew of the Philistines two hundred men; and David brought their foreskins, and gave them in full tale to the king."

Associated with the direct motive for taking trophies there is an indirect motive, which probably aids considerably in developing the custom. Numerous facts unite to prove that the unanalytical mind of the savage thinks the qualities of any object reside in all its parts; and that, among others, the characteristics of human beings are thus conceived by him. From this we found there arise such customs as swallowing parts of the bodies of dead relatives, or their ground bones in water, with the view of inheriting their virtues; devouring the heart of a slain brave to gain his courage, or his eyes in the expectation of seeing further; avoiding the flesh of certain timid animals, lest their timidity should be acquired. A further implication of this belief that the spirit of each person is diffused throughout him is, that possession of a part of his body gives possession of a part of his spirit, and, consequently, a power over his spirit: one corollary

being that anything done to a preserved part of a corpse is done to the corresponding part of the ghost; and that thus a ghost may be coerced by maltreating a relic. Hence the origin of sorcery all over the world; hence the rattle of dead men's bones so prevalent with primitive medicine-men; hence "the powder ground from the bones of the dead" used by the Peruvian necromancers; hence the portions of corpses which our own traditions of witchcraft name as used in composing charms.

Besides proving victory over an enemy, the trophy therefore serves for the subjugation of his ghost; and that possession of it is, at any rate, in some cases, supposed to make his ghost a slave, we have good evidence. The primitive belief everywhere found, that the doubles of men and animals slain at the grave accompany the double of the deceased, to serve him in the other world—the belief which leads here to the immolation of wives, who are to manage the future household of the departed, there to the sacrifice of horses needed to carry him on his journey after death, and elsewhere to the killing of dogs as guides—is a belief which, in many places, initiates the kindred belief that, by placing portions of bodies on his tomb, the men and animals they belonged to are made subject to the deceased. Hence the bones of cattle, etc., with which graves are in many cases decorated; hence the placing on graves the heads of enemies or slaves, as above indicated; and hence a like use of the scalp. Concerning the Osages, Mr. Tylor cites from McCoy and Waitz the fact that they sometimes "plant on the cairn raised over a corpse a pole with an enemy's scalp hanging to the top. Their notion was that, by taking an enemy and suspending his scalp over the grave of a deceased friend, the spirit of the victim became subjected to the spirit of the buried warrior in the land of spirits." The Ojibways have a like practice, of which a like idea is probably the cause.

A collateral development of trophy-taking, which eventually has a share in governmental regulation, must not be forgotten. I refer to the display of parts of the bodies of criminals.

In our more advanced minds the enemy, the criminal, and the slave, are well discriminated; but they are little discriminated by the primitive man. Almost or quite devoid as he is of the feelings and ideas we call moral—holding by force whatever he owns, wresting from the weaker the woman or other object he has possession of, killing his own child without hesitation if it is an incumbrance, or his wife if she offends him, and sometimes proud of being a recognized killer of his fellow-tribesmen—the savage has no distinct ideas of right and wrong in the abstract. The immediate pleasures or pains they give are his sole reasons for classing things and acts as good or bad. Hence, hostility and the injuries he suffers from it excite in him the same feeling, whether the aggressor is without the tribe or

within it: the enemy and the felon are undistinguished. This confusion, now seeming strange to us, we shall understand better on remembering that, even in early stages of civilized nations, the family-groups which formed the units of the national group were in large measure independent communities, standing to one another on terms much like those on which the nation stood to other nations; that they had their small blood-feuds as the nation had its great blood-feuds; that each family-group was responsible to other family-groups for the acts of its members, as each nation to other nations for the acts of its citizens; that vengeance was taken on innocent members of a sinning family, as vengeance was taken on innocent citizens of a sinning nation; and that so the inter-family aggressor (answering to the modern criminal) stood in a like relative position with the international aggressor. Hence the naturalness of the fact that he was similarly treated. Already we have seen how, in mediæval days, the heads of slain family-enemies (murderers of its members or stealers of its property) were exhibited as trophies. And from the Salic law we also learn "that there was beside each dwelling a forked gibbet, as there was beside the public tribunals." Since, at the same time, the heads of foes slain in battle were brought back and displayed—since it is alleged by Lehuerou, on the authority of Strabo, that sometimes such heads were nailed up to the chief door of the house along with those of private foes—we have evidence that identification of the public and the private foe was associated with the practice of taking trophies from them both. A kindred alliance is traceable in the usages of the Jews. Along with the slain Nicanor's head, Judas orders that his hand be cut off; and he brings both with him to Jerusalem as trophies: the hand being that which he had stretched out in blasphemous boasts. And this treatment of the transgressor who is an alien is paralleled by the treatment of non-alien transgressors by David, who, besides hanging up the corpses of the men who had slain Ishbosheth, "cut off their hands and their feet."

It may, then, be reasonably inferred that the display of executed felons on gibbets, or their heads on spikes, originates from the bringing back of trophies taken from slain enemies. Though usually a part only of the slain enemy is fixed up, yet sometimes the whole body is, as when the dead Saul, minus his head, was fastened by the Philistines to the wall of Bethshan; and that fixing up the whole body of the felon is more frequent, probably arises from the fact that it has not to be brought from a great distance, as would usually have to be the body of an enemy.

Though no direct connection exists between trophy-taking and ceremonial government, the foregoing facts reveal such indirect connections as make it needful to note the custom. It enters as a factor into the three forms of control—social, political, and religious.

If, in primitive states, men are honored according to their prowess —if their prowess is estimated here by the number of heads they can show, there by the number of jawbones, and elsewhere by the number of scalps—if such trophies are treasured up for generations, and the pride of families is proportioned to the number of them taken by ancestors—if of the Gauls in the time of Posidonius we read that "the heads of their enemies that were the chiefest persons of quality they carefully deposit in chests, embalming them with the oil of cedars, showing them to strangers, glory and boast" that they or their forefathers had refused great sums of money for them—then, obviously, a kind of class-distinction is initiated by trophies. On reading that in some places a man's rank varies with the quantity of bones in or upon his dwelling, we cannot deny that the display of these proofs of personal superiority originates a regulative influence in social intercourse.

As political control evolves, trophy-taking becomes in several ways instrumental to the maintenance of authority. Beyond the awe felt for the chief whose many trophies show his powers of destruction, there comes the greater awe which, on growing into a king with subordinate chiefs and dependent tribes, he excites by accumulating the trophies others take on his behalf; rising into dread when he exhibits in numbers the relics of slain rulers. As the practice assumes this developed form, the receipt of such vicariously-taken trophies passes into a political ceremony. The heap of hands laid before an ancient Egyptian king served to propitiate; as now serves the mass of jawbones sent by an Ashantee captain to the court. When we read of Timour's soldiers that "their cruelty was enforced by the peremptory command of producing an adequate number of heads," we are conclusively shown that the presentation of trophies hardens into a form expressing obedience. Nor is it thus only that a political effect results. There is the derived kind of governmental restraint produced by fixing up the bodies or heads of felons.

Though offering part of a slain enemy to propitiate a ghost does not enter into what is commonly called religious ceremonial, yet it obviously so enters when the aim is to propitiate a god developed from an ancestral ghost. We are shown the transition by such a fact as that, in a battle between two tribes of Khonds, the first man who "slew his opponent struck off his right arm and rushed with it to the priest in the rear, who bore it off as an offering to Laha Pennoo in his grave;" Laha Pennoo being their "god of arms." Joining with this such other facts as that, before the Tahitian god Oro, human immolations were frequent, and the preserved relics were built into walls "formed entirely of human skulls," which were "principally, if not entirely, the skulls of those who have been slain in battle," we are shown that gods are worshiped by bringing to them, and accumulating round their shrines, these portions of enemies killed—killed,

not unfrequently, in fulfillment of their supposed commands. And the inference is verified on seeing similarly used other kinds of spoils. The Philistines, besides otherwise displaying relics of the dead Saul, put "his armor in the house of Ashtaroth." By the Greeks the trophy, formed of arms, shields, and helmets, taken from the defeated, was consecrated to some divinity; and the Romans deposited the spoils brought back from battle in the temple of Jupiter Capitolinus. Similarly of the Feejeeans, who are solicitous in every way to propitiate their bloodthirsty deities, we read that, "when flags are taken they are always hung up as trophies in the *mbure*," or temple. That hundreds of gilt spurs of French knights vanquished by the Flemish in the battle of Courtrai were deposited in the church of that place, and that in France flags taken from enemies were suspended from the vaults of churches (a practice not unknown in Protestant England), are facts that might be joined with these, did not so joining them imply the impossible supposition that Christians think to please "the God of love" by acts like those used to please the diabolical gods of cannibals.

Because of inferences to be hereafter drawn, one remaining general truth must be named, though it is so obvious as to seem scarcely worth mention. Trophy-taking is directly related to militancy. It begins during a primitive life that is wholly occupied in hostilities with men and animals; it develops with the growth of conquering societies in which perpetual wars generate the militant type of structure; it diminishes as growing industrialism more and more substitutes productive activities for destructive activities; and it is a truism to say that complete industrialism necessitates entire cessation of it.

The chief significance of trophy-taking, however, has yet to be pointed out. The reason for dealing with it under the general head of Ceremonial Government, though in itself scarcely to be classed as a ceremony, is that it furnishes us with the key to a large class of ceremonies which have prevailed all over the world among the uncivilized and semi-civilized. From the practice of cutting off and taking away portions of the dead body, there grows up the practice of cutting off portions of the living body.

OPIUM AND ITS ANTIDOTE.[1]

By CHARLES RICHET.

OPIUM is the juice of the poppy, and, as there are many varieties of the poppy, so too are there many kinds of opium; the mode of collecting the juice is, however, always the same. In Egypt, Syria, and India, the three countries which produce opium, a number

[1] From the *Revue des Deux Mondes*; translated and condensed by J. Fitzgerald, A. M.

of semicircular incisions are made in the capsule of the poppy, and the juice which exudes is carefully gathered. This juice, on being dried in the sun, becomes of a dark color, thickens, and forms a brown, firm paste: this is opium. Laudanum is a solution of opium in alcohol and water. Both opium and laudanum are to be regarded as a mixture of several similar but not identical substances. Since the time of Derosne (1804) and Robiquet (1817), who first isolated narcotine and morphine, chemists have very carefully investigated the different chemical compounds occurring in opium. Thus they have discovered codeine, narceine, thebaïne, papaverine, and other substances, all of them bases, i. e., bodies that unite with acids to form crystallizable salts.

These bases do not all affect in the same way the organic functions. Thus, narcotine possesses very little or no soporific power: two grammes of it can be injected without perceptible effect, while a centigramme of morphine is quite sufficient to produce therapeutic and physiological results. Thebaïne does not cause sleep, and in animals produces convulsions like those caused by strychnine, while morphine in the same dose produces deep comatose sleep. Another curious thing about these opium alkaloids is, that they do not act alike on man and animals, as has been demonstrated by Claude Bernard. Man is specially sensitive to the action of morphine, while thebaïne is almost without effect upon his nervous system: animals, on the other hand, feel the effects of morphine only when it is given in large doses, while thebaïne is for them a violent poison. So, too, with belladonna, and atropine, its active principle, they are a deadly poison for man, but almost without effect on rabbits: the dose of atropine that would suffice to kill ten men would hardly be enough to kill one rabbit. The difference is not so great with respect to morphine, yet morphine specially affects man; hence in this article we will consider only this one opium alkaloid.

When, in "Le Malade imaginaire," honest *Argan* is asked why opium causes sleep, his artless reply is, "Quia habet proprietatem dormitivam." Nowadays we are not content with this kind of explanation, and some authors have sought for the "dormitive property" of opium in the state of the cerebral circulation; and, though the true cause has not yet been certainly established, still it is something that research has been made.

It is not yet positively decided whether opium produces anæmia or whether it produces congestion of the brain; indeed, we know little more than did *Argan*, namely, that it sets one asleep. This sleep, however, is in some respects different from ordinary sleep. From thirty to sixty minutes after taking opium one feels a slight excitation; there is a general feeling of buoyancy and contentment, soon followed by drowsiness and a state of reverie rather than of dreaming. There is a pleasurable feeling of *abandon*, and an agreeable

sense of torpor creeps over the whole frame; the thoughts are like the ever-shifting scenes of a phantasmagoria, on which we passively gaze, without will or effort to alter the series. Still, so long as the intoxication is not deep, such effort is possible. One feels that he is falling asleep, and that if he would but bestir himself he might overcome his drowsiness. But little by little the legs grow heavy, the arms fall to the sides almost powerless, and the weighted eyelids refuse to remain open. A dreamy, rambling sort of thinking still goes on, and there is as yet no sleep; we are still conscious of the world around. We indistinctly hear the tic-tac of the clock and the rumble of passing vehicles, but it is as though, so to speak, another person were listening and not we. The active, conscious *Me* exists no more, and another personality seems to have taken its place. Gradually everything becomes more and more indistinct, our thoughts are enveloped in a haze, we feel ourselves detached from matter, detached from our bodies, and transformed into thought, which flits about, so to speak, becoming more and more brilliant, but at the same time more and more confused. Then the outer world disappears, and there remains only an inner world, sometimes full of tumult and delirium, and producing feverish excitement, or, as is more frequently the case, calm and quiet, and full of delightful repose. This intoxication is purely psychical, and far superior to the intoxication produced by alcohol or hasheesh, for, though hasheesh gives one a few hours of insanity, opium gives sleep, and with this boon there is nothing that can compare. One must have suffered from insomnia in order to appreciate the value of opium. It brings sleep, and it banishes pain.

It is one of the most powerful agents we possess for modifying the sensibility, but whether it does this by acting upon the sensor nerves or on the brain we know not with certainty. Even where it does not procure sleep, it has the singular power of calming the excitability of the nerves, and of subduing that morbid state of the sensibility called by physicians hyperæsthesia. It has been observed that when it reduces hyperæsthesia it does not cause sleep, all its force seemingly being spent in combating pain. In cases of stubborn neuralgia opium appeases suffering, and a larger dose is required to produce sleep. But is it not enough that it allays the irritability of a diseased nerve? Some persons cannot live without opium, and they swallow enormous quantities of it without perceptible effect. Herein opium differs widely from alcohol. Alcohol is cumulative in its effects, and the more one is addicted to its use, the more easily is he intoxicated by it. One does not become habituated to alcohol intoxication, but with opium the case is different; one may become so accustomed to it as to be able to drink daily a litre of laudanum, twenty drops of which would be a strong enough medicinal dose for a non-habituated person.

In China there is the same popular demand for opium that exists in Europe for alcohol and tobacco. The use of opium does not date very far back, and it is probably the only innovation that China has adopted from the West. The importation of opium from India into China amounted in 1798 to 300 tons, in 1863 to 3,000 tons, in 1866 to 3,903, and since then the increase has been still more rapid.[1]

Opium is chewed, or smoked in a pipe, the latter mode of using it being the more common. The bowl of a long-stemmed pipe is filled with the drug, and, as the opium swells and adheres to the pipe, a needle is in constant use to keep open an air-passage. As the drug burns with difficulty, the smoker must have a light ready at hand for use whenever his pipe goes out.

The number of opium-smokers is considerable, but the great majority of them use the drug only in moderation. The wealthiest mandarins, the most intelligent merchants, smoke opium, as do the humblest coolies. The use of opium is like the use of tobacco among ourselves; nor does it produce any greater mischief, at least among the well-to-do classes; but with the common people it is different. There are establishments specially devoted to opium—smoking-places where, for a trifling sum of money, one may gratify this appetite. Rarely does a smoker leave before he is fully under the influence of the drug, just as the drunkard does not quit the gin-shop until he is fuddled. So used, opium is certainly a dangerous poison, and, according to the testimony of all travelers, the wretches who daily commit such excesses speedily fall to a fearful state of degradation, both moral and physical. Pale, wan, gaunt, shambling along with difficulty, they must have recourse to artificial stimulation in order to regain a part of their wasted energy. Still the injurious effects of opium have in all probability been very much exaggerated: the number of deaths caused by the abuse of the drug is not very great; and many of those who smoke it, even in considerable quantity, retain unimpaired their mental faculties. True, the digestive functions rarely escape impairment. Dyspepsia and general emaciation are the result of this sad habit; but, however that may be, China is not yet by any means on the brink of ruin, and, if she is in a state of decadence, the blame does not attach to opium.

Opium has its antidote: just as we can produce sleep, so too can we produce sleeplessness, by the employment of a mind-poison whose effects are diametrically opposite to those of the other. The antidote of opium is coffee. One hundred years ago coffee was almost unknown, but now there is hardly another beverage that is so widely distributed. Every one has it in his power to judge of the effects of coffee. For some persons it is a stimulus necessary for the performance of intellectual work. In others it produces a painful state of insomnia:

[1] The native production of opium has of late years attained very considerable proportions.—*Trans.*

taken even in weak doses it causes restlessness and anxiety, a sort of feverish activity altogether different from the indolent activity of opium. Under the action of opium the will seems to be lulled to sleep and the imagination runs riot. But under the influence of coffee the imagination is hardly stimulated at all, while there does appear to be excitation of the will. Did I not fear being suspected of having a theory to defend, I should say that the faculties of will and consciousness seem to be superexcited: there is, as it were, a constant strain on attention and memory, whereas in the case of alcohol, hasheesh, and opium, there is a relaxing of attention. Hence coffee produces a true intoxication that fatigues one far more than does the somnolent intoxication of opium, but it leads to the same result. In striving to do too much, the mind does less: under stimulation the will is impaired; and the perfect equilibrium of the mental faculties is disturbed as well by excess as by defect of will.

Coffee is said to produce cerebral anæmia, while opium and alcohol cause congestion; but this theory still needs confirmation. Nevertheless, the part played by coffee in general nutrition is very well understood. It retards organic combustion, and hence it is an *aliment d'épargne*—a food-stuff that effects a saving of other food-stuffs. In the normal state there is always going on within our tissues a multitude of chemical actions, the final result of which is heat-production and liberation of carbonic acid. This carbonic acid passes into the venous blood, and the venous blood, on reaching the lungs, parts with its carbonic acid. Thus the quantity of the carbonic acid is, to some extent, the expression of the nutritive activity. Now, on taking coffee, though no greater quantity of oxygen be inhaled, and without increasing the ration of food, the quantity of the carbonic acid is reduced, and yet the amount of force is not lessened. As illustrating this doctrine, it is usual to cite a fact observed among Belgian miners, who can perform a considerable amount of work almost without food, their strength being maintained solely by the absorption of a large quantity of coffee. Hence coffee is a food-stuff which moderates nutrition by lessening the activity of the chemical transformations incessantly going on within the tissues.

THE TELEPHONE AND HOW IT WORKS.

By GEORGE M. SHAW.

AMONG the innumerable uses of electricity none is more remarkable than its employment for the transmission of sound. The ultimate mystery of the action we cannot, of course, undertake to explain, but the mechanism by which it is produced is by no means difficult to understand.

If a wire, from a galvanic battery such as is shown in Fig. 1, through which a current of electricity is passing, be wound around a piece of steel or soft iron, as represented in Fig. 2, some curious things will happen. If the bar be soft iron, it will be made magnetic, and kept in that condition as long as the current continues to pass round it, and its ends will then attract and hold bits of iron, but drop them when the battery is taken away. If the bar be of steel, instead of soft iron, it will be magnetized and attract iron just as before; but, unlike the soft-iron bar, it will *keep* its magnetism and attract the iron even after the battery is removed. Its magnetism will be permanent. Since, however, electricity made the magnet, we can, in turn, make the magnet a source of electricity. Suppose the magnetized steel bar has attracted and is holding on to a piece of iron. We can now take the battery away and join the ends of the wire, as in Fig. 3; then, if the piece of iron be pulled off and stuck on again, a current of electricity will run through the wire every time it is done. Electricity produced in this way is called magneto-electricity, and the current in the wire is said to be an induced electric current. If, now, the wire from bar No. 1 (Fig. 4), be extended to a distance, and coiled around another magnetized bar (No. 2), the currents induced in it, by making and breaking the contact of the piece of soft iron with the first magnet, will simultaneously affect the magnetism in the distant magnet also. Though the magnets be a mile or a hundred miles apart, the disturbance in one is immediately and equally manifested in the other.

FIG. 1.

FIG. 2.

But, what is still more remarkable, these induced currents may be sent through the wire without the actual contact of the soft iron with the steel bar. If this piece of iron is brought very near to one magnet without touching it, and then withdrawn, an electric thrill or wave is induced in the wire which is felt in the distant magnet, just as if the contact had been actually made and broken. And so if we play the piece of soft iron backward and forward, before the magnet, no matter how rapidly or slightly, each motion is felt as an electric pulse in the magnet at the other end. To borrow a metaphor from life, it is as if the close approach and quick oscillation of the piece of soft iron fretted or tantalized the magnet, and sent a series of electrical shudders through the iron nerve.

We have here the fundamental principle of the telephone. No galvanic battery is employed to furnish an electrical current, as in the case of the telegraph; but the currents in the wires are produced by the motions of the piece of soft iron near the magnet. Thus far we have represented these motions in a very rude and coarse way, as if the piece of iron were vibrated backward and forward by the hand; but what we have really to deal with is something infinitely more delicate than this. The piece of soft iron of which we have been speaking, shown at *a*, Figs. 3 and 4, represents what is called the *diaphragm* of the telephone, which is a thin, circular sheet of iron, a couple of inches in diameter, held by its rim, and adjusted so that its centre comes very close to the end of the magnetized bar. And the motions which now concern us are simply the vibrations produced in this iron membrane by the beats against it of agitated air. Everybody knows that sounds are propagated through the aërial medium by waves that travel swiftly from their sources, and that we hear them because the waves strike in rapid succession upon the drum of the ear. It is also well understood that these waves differ greatly in their rates, depending upon the rapidity of vibration in the sounding body; and, moreover, that they are very complex, there being waves within waves of various orders in a single tone. It is the special complexity of these wave-systems, in the different cases, that gives those peculiarities of tone that mark different musical instruments and distinguish the voice in different individuals. These

FIG. 3.

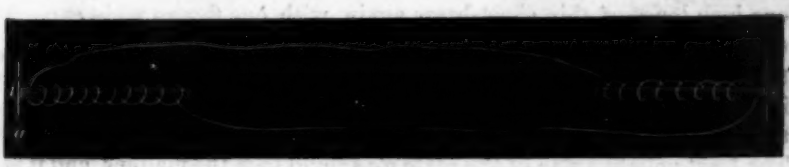

FIG. 4.

waves, started by a person talking, beat against the diaphragm of the telephone as they beat against the tympanum of the ear, and throw it into vibrations, which are reproduced in the thrills of the magnet that again excite tremors in the wires, and these, affecting the magnet, at the other end set the other diaphragm into vibration, and this gives out a new set of air-waves which, falling on the tympanum of the listener, reproduces the original sound or voice. The arrangement being the same at each end, the machine, of course, works both ways, so that when a person is talking to the distant diaphragm the direction is reversed, and the sounds are emitted by

the diaphragm near by, and thus the original talker gets his response. The action set up in one telephone is instantaneously repeated or copied by the other. And so by this marvelous chain of effects a person discoursing, apparently, to a piece of iron, may be intelligibly heard hundreds of miles away, and a conversation kept up between the distant parties as if they were in the same room. The "ear-shot" from the beginning of the world has been but a few hundred feet; by the invention of this little contrivance it is now extended to hundreds of miles.

So much for the theory of the telephone; let us now note how it may be practically constructed. To make one, procure a tube, *b b* (Fig. 5), of thin sheet-brass, one inch long, two inches in diameter,

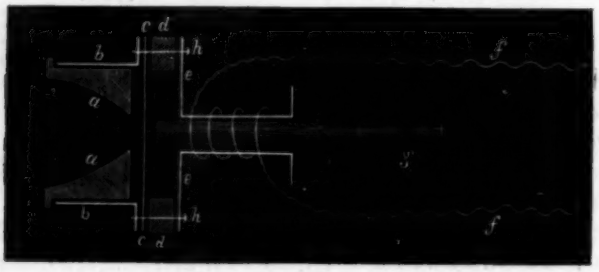

FIG. 5.

and with a flange one-half inch wide. Then from a ferrotype-plate—the photographer's "tin-type"—cut a round plate, shown edgewise, at *c c*, to cover the tube *b b* over the flange. This is the vibrator or diaphragm. Next cut a wooden ring or "washer," *d d*, the width of the flange, and about one-eighth of an inch thick. Then make a spool, *e e*, one inch long, of thin sheet-brass again, with one flange wide enough to cover the wooden ring, the tube of the spool being made so as to fit tightly the magnet *g*, which is a strongly-magnetized steel rod, four inches long and three-eighths of an inch in diameter. The parts will then fit together, and may be screwed firmly through the flanges *b b*. The least polished side of the plate *c c* should face the magnet, and it is well to scrape the part opposite the end of the bar, so as to expose the iron. The spool is to be wound with about fifty yards of No. 36 or 38 silk-covered copper wire, the thickness of a bristle. The magnet is then shoved in, till it nearly touches the plate *c c*. After joining the ends of the spool-wire to the line-wires *f f*, that run to another instrument just like it, the telephone will be ready for use. It is important to concentrate the voice upon a narrow space at the middle of the plate, and for this purpose a movable wooden mouth-piece, *a a*, is used, with an opening at the bottom about the size of a dime. This mouth-piece should fit neatly, and reach to within about one-eighth of an inch of the diaphragm.

Fig. 6 represents a section of Bell's telephone. *E E* is the diaphragm, *F* the tube, *B* the silk-covered wire wound upon the spool, extending *C C*, to the binding-screws *D D*, where they are connected with the line-wires. The magnet *A* has its distance from the diaphragm adjusted by the screw at the opposite end. Fig. 7 represents the form and aspect of the instrument as used. It is about five or six inches long and two and a half inches broad at its widest part. In sending a message, the instrument is held to the mouth,

FIG. 6.

and the words distinctly spoken in ordinary tones or even a whisper. The instrument is then held to the ear to receive the answer. Instead of this, two telephones connected may be used at each station, so that one may be held to the ear all the time, while the other is used for telephoning, as illustrated in Fig. 8; and this one, too, in hearing a long message, or in a noisy room, may be held to the other ear, and so shut out all other sounds. This also gives two persons a chance to hear at the same time, by giving a telephone to each.

Several telephones may be connected together in one office, so that any number of persons, by having one each, may hear the same message. In singing, each singer has a telephone. At the late fair of the American Institute, we were one evening listening to a quartet of college-boys, uproariously singing "Upidee i-dee-i-da," in the *Tribune* Building, through six miles of wire, when suddenly all was still. "Hello!" we shouted. "Hello you!" was answered back. "What's the matter?" "Big fire in Leonard Street. The fire is—" "Never mind the fire; go on with the singing," we rejoined, and the singing went on with "The Red, White, and Blue." The impression produced by listening to a communication through this instrument has been aptly described as follows: "The voice, whether in speaking or singing, has a weird, curious sound in the telephone. It is in a measure ventriloqual in character; and, with the telephone held an inch or two from the ear, it has the effect as if some one were singing far off in the building, or the sound were coming up from a vaulted cellar or through a massive stone-wall." The singing or speaking is heard microscopically, as it were, or rather microphonically, but wonderfully distinct and clear in character. The enchantment of distance is there, and one listens as to sounds from fairy-land.

The longest distance at which conversation has been carried on, so far, through the telephone, is about 250 miles. With a submarine cable conversation has been carried on between England and France across the English Channel. Conversation has also been held through the bodies of sixteen persons standing hand-in-hand.

FIG. 7.

The telephone has been regarded as a toy, or a curiosity to be played with; but, while it is undoubtedly extremely interesting as a novelty, it is very much more than this; it is, scientifically and practically, a great success. There are, undoubtedly, difficulties in its use, but, considering that it is a contrivance but of yesterday, the wonder is that it is so perfect. The telegraph was much longer regarded as an impracticable invention, and it is impossible to say how soon the telephone may not take rank among the necessities of common life. If we may trust the analogies of experience, its difficulties are certain to be overcome, although it will probably never meet the exaggerated expectations of many people. Some of the obstacles to the realization of the popular impression of its capabilities have been so well stated in *Chambers's Journal*, by a gentleman skilled in the working of the telegraph, and who made a series of interesting experiments on the telephone, that we may fitly close our article by making free extracts from his paper, accompanied by some slight revision: "When a telegraphist first gets into his hand this beautifully simple and electrically delicate instrument, his first inclination is to test its carrying-power. This is, of course, a closet experiment, not working with actual telegraph-line, but with 'resistance' equivalent to a telegraph-line of stated length. An experiment of this nature gives better results than could be obtained by a veritable line, because the insulation is, so to speak, perfect. No leakage at undesigned points of contact, or disturbance from unfavorable atmospheric conditions, is felt, and the experiment is entirely under the observer's control. The apparatus used is designed to offer the same labor for the electric current to overcome as would be offered by a stated length of outside telegraph-line. This artificial resistance is nicely graduated, and, as the method of testing was suggested by Ohm, a German electrician, the unit of resistance is termed an 'ohm.' Removing the telephone to such a distance that the two observers were 'out of ear-shot,' the test with resistance was tried, and with a resistance of 1,000 ohms—roughly speaking, equal to seventy miles of a well-constructed line—the sound was perfect, although not very loud. Every articulation of

the speaker at the other end could be distinguished so long as silence was maintained in the room, or so long as no heavy lorry rumbling over the stones outside sent in harsh noises which drowned the faint whisper of the instrument. The resistance was gradually raised to 4,000 ohms—nearly 300 miles—with like favorable results; and for some little distance beyond, articulation could still be made out. But, by the time 10,000 ohms had been applied, putting the speaker at a distance of, say, 700 miles, sound only, but not articulate sound, reached the ear. The tone was there, and every inflection of the voice could be followed; but articulation was absent, although the listener strained every nerve to catch the sound, which the speaker, as

FIG. 8.

was afterward ascertained, was shouting in a loud, clear voice. The prolonged notes of an air sung could be heard with the resistance named, but again no words could be distinguished."

The next experiment was to join up the telephones in the office with different line-wires in succession going to various distances, and working with different kinds of telegraph-instruments. "When this was done, the real obstacle to telephonic progress at once asserted itself in the shape of 'induction.' The first wire experimented with was partly 'overhouse' and partly underground, and the offices upon it were working A B C, or printing-instruments. It is difficult to render clear to the person ignorant of telegraphic phenomena the idea

expressed by the word *induction*. Briefly, it may be put thus: that, when a strong electric current is passing on a wire, it has the faculty of setting up a current of opposite character in any wire not then working, or working with a feebler current, that may be in its vicinity. The why or the wherefore cannot be explained, but there is the fact.

"In various recent articles on the telephone, mention has been made of 'contact' as the cause of disturbance. This word, however although it has been used by telegraphists, is misleading, and can only be used as an endeavor to express popularly an electric fact. Actual contact of one wire with another would spoil the business altogether. A wire bearing an electric current seems to be for the time surrounded, to an undefined distance, by an electric atmosphere, and all wires coming within this atmosphere have a current in an opposite direction set up in them. This is as near an explanation of the phenomena of induction as the state of telegraph science at present affords. Now, the telephone works with a very delicate magnetic current, and is easily overpowered by the action of a stronger current in any wire near which the telephone-wire may come. To work properly, it 'requires a silent line.'

"In the place where the observations were made, there were a large number of wires traveling under the floor, along passages to the battery-room, and to a pole on the outside, whence they radiate, or out to a pipe underground, where many gutta-percha-covered wires lie side by side. On applying the ear to a telephone joined into a circuit working in such an office, a curious sound is heard, comparable most nearly to the sound of a pot boiling. But the practised ear could soon separate the boiling into distinct sounds. There was one masterful Morse instrument—probably on the wire lying nearest the one on which we were joined up—whose peremptory 'click, cli-i-i-ck, click,' representing 'dot, dash, dot' on the printed slip we read from, could be heard over all. Then there was the rapid whir of a fast-speed transmitter sending dots and dashes at express speed by mechanical means; and, most curious of all, the 'rrrrr-op, rr-op, rrrrrrr-rrrrrr-op, rrrrr-op, rr-op' of the A B C, or printing-instrument, the deadliest foe to the telephone in its endeavors to gain admission into the family of telegraph-instruments. There may be reason in this, for as the A B C, or printing-instrument, is the instrument used for private telegraphy, or for the least important public offices, because it requires no 'code' to be learned by the manipulator, so it would likely be the first to be displaced if an acoustic telegraph permanently took the field. So the sentient little A B C opens its mitrailleuse-fire on the intruder, on whose delicate currents, in the words of an accomplished electrician, it plays 'old Harry.' The peculiar character of the sounds we borrow on the telephone from this instrument arises from the fact that, as the needle flies round the dial, a distinct current

or pulsation passes for each letter, and the final 'op' we have tried to represent shows the stoppage of the needle at the letters as words were spelled out.

"It must not be understood that the *sounds* of those various instruments are actually heard in the telephone. What happens is, that the currents stealing along the telephone-wire by induction produce vibrations in the diaphragm of that instrument, the little metal membrane working on the magnet in ready response to every current set up the latter. When it is remembered that the principle of the telephone is that the sound-caused vibrations in the filmy diaphragm at one end create similar but magnetically-caused vibrations in the diaphragm at the other end, and so reproduce the sound, it will be obvious why the rapid roll of the A B C currents, or the swift sending of the fast-speed transmitter, when brought by induction into the telephone-wire, cause disturbances in the sound-vibrations, and thereby cripple the instrument. One instrument of either kind named would have a certain effect, but one Morse would not have any greatly prejudicial effect. But a number of Morses going together, such as were heard in our experiments, would combine to be nearly as bad as one A B C or fast-speed Morse. So delicate is the diaphragm to sound (and necessarily so) that, in all experiments with the telephone itself, every sound from without broke in, giving an effect like the well-known 'murmur of the shell.'"

"Joining up our wire now to a more distant station at some miles along the railway, and having on its poles a number of what are known as 'heavy' circuits, the pot-boiling sound assumed even more marked characteristics. The A B C no longer affected us; but a number of Morse instruments were in full gear, and the fast-speed transmitter was also at work. While we were listening, the circuit to which we were joined began to work, and the effect was literally electrical. Hitherto we had only borrowed currents—or, seeing they were so unwelcome, we might call them currents thrust upon us—and the sounds, though sharp and incessant, were gentle and rather low. But, when the strong current was set up in the wire itself, the listener who held one of our telephones nearly jumped from the floor when an angry 'pit-*pat*, pit-*pat*, pit-*pat*-pit' assailed his ear, causing him to drop the instrument as if he had been shot. It was a result none of us had expected, for it did not seem possible that the delicate metal diaphragm and the little magnet of the telephone could produce a sound so intense. Of course, it was only intense when the ear was held close to the orifice of the instrument. Held in the hand away from the ear, the telephone now made a first-rate 'sounder,' and we could tell without difficulty not only the signals that were passing, but found in it a more comfortable tone than that given by the Morse sounder in common use.

"Other experiments of a like character led to results so similar

that they may be left unnoticed; and we proceed now to describe one of a different character, designed to test the telephone itself. At a distance of about half a mile, access was obtained to a Morse instrument in private use, and joined to the office by 'overhouse' wire. Dividing our party and arranging a programme of operations, two remained with a telephone in the office, while other two, of whom the writer was one, proceeded with the second telephone to the distant instrument. By an arrangement which a practical telegraphist will understand, the key of the Morse was kept in circuit, so that signals could be exchanged in that way. It may be noticed, however, that this was hardly necessary, as the diaphragm of the telephone can be used as a key, with the finger or a blunt point, so that dot and dash signals are interchangeable, should the voice fail to be heard. As the wire in this instance traveled almost alone over part of its course, we were in hopes that induced currents would be conspicuous by their absence. In this we were, however, disappointed, for the pot was boiling away, rather more faintly, but with the 'plop-plop-plop' distinctly audible, and once more a sharp masterful Morse click was heard coming in now and again. The deadly A B C was, however, absent, so that our experiment proved highly successful. For some reason or another—probably an imperfect condition of the wire, or the effects of 'induction' over and above what made itself audible to us—the spoken sounds were deficient in distinctness; but songs sung at either end were very beautifully heard, and, indeed, the sustained note of sung words had always a better carrying-power than rapidly-spoken words. Every syllable and every turn of melody of such a song as 'My Mother bids me bind my Hair,' sung by a lady at one end, or 'When the Heart of a Man,' sung at the other, could be distinctly heard, but with the effect before noticed, that the voice was muffled or shut in, as if the singer were in a cellar, while it was not always possible to say at once whether the voice was that of a man or a woman.

"In the course of some domestic experiments it was remarked that, in playing the scale downward from C in alt. on the piano, the result to the listener was a 'tit' only for the four upper notes, although all below that had a clear 'ting,' and the octaves below were mostly distinct, although at the low notes of the piano the sound was again lost. The ringing notes of a musical-box were not so successful, but, with close attention, its rapid execution of 'Tommy Dodd' could be well enough made out. An endeavor was made to catch the ticking of a watch, but this was not successful, and the experiment is not recommended, as the near presence of a watch to a magnet is not desirable; and the watch exposed to it in this instance was, it is thought, affected for a short time thereafter, although it received no permanent damage.

"The observations made in the course of these experiments convinced those present that the telephone presents facilities for the

dangerous practice of 'tapping the wires,' which may make it useful or dangerous, according as it is used for proper or improper purposes. It might be an important addition for a military commander to make to his flying cavalry; as an expert sound-reader, accompanying a column sent to cut off the enemy's telegraph-connections, might precede the act of destruction by robbing him of some of his secrets. The rapidity and simplicity of the means by which a wire could be 'milked,' without being cut or put out of circuit, struck the whole of the party engaged in the various trials that are described above. Of course, the process of tapping by telephone could not be carried out if the instrument in use was an A B C or single needle, or if the wire was being worked duplex or with a fast-speed Morse, for in these cases the sounds are too rapid or too indefinite to be read by ear. The danger is thus limited to ordinary sounder or Morse telegraphs; but these still form the mainstay of every public system.

"Since the trials above described were made, the newspapers have recorded a beautiful application, by Sir William Thomson, of the electric part of the telephone to exhibit at a distance the motions of an anemometer; the object being to show the force of air-currents in coal-mines. This is a useful application of an electric fact, and doubtless points the way to further discoveries. But it is to be noticed that the experiment, interesting as it is, hardly comes under the head of a tele*phone*, what is reproduced at a distance being not sound but motion.

"Obviously the invention cannot rest where it is; and no one more readily than the practical telegraphist will welcome an instrument at once simple, direct, and reliable. Even in its present form the telephone may be successfully used where its wire is absolutely *isolated* from all other telegraph-wires. But the general impression is that its power of reproducing the sound must be intensified before its use can become general, or come up to the popular expectation."

The realization of so marvelous a device as the telephone cannot fail to stimulate speculation as to where such wonders will stop. If words may be converted into electricity and back again into words, what is to hinder their being converted into something more lasting than electricity—something that will endure, so that spoken words may be reproduced in the future exactly as spoken now; that persons, though dead, may yet speak? What is to hinder? Nothing! The thing is already done; the spirit of the Phonograph has taken on more than a shadowy form, as will be explained to our readers next month. And what next?—

> "Ah! Science, give us one more link,
> That we may hear our neighbors think."

TECHNICAL EDUCATION.[1]

By Prof. T. H. HUXLEY, F. R. S.

ANY candid observer of the phenomena of modern society will readily admit that bores must be classed among the enemies of the human race; and a little consideration will probably lead him to the further admission that no species of that extensive genus of noxious creatures is more objectionable than the educational bore. Convinced, as I am, of the truth of this great social generalization, it is not without a certain trepidation that I venture to address you on an educational topic. For, in the course of the last ten years, to go back no further, I am afraid to say how often I have ventured to speak of education, from that given in the primary schools to that which is to be had in the universities and medical colleges; indeed, the only part of this wide region into which as yet I have not adventured is that into which I propose to intrude to-day.

Thus I cannot but be aware that I am dangerously near becoming the thing which all men fear and fly. But I have deliberately elected to run the risk. For, when you did me the honor to ask me to address you, an unexpected circumstance had led me to occupy myself seriously with the question of technical education; and I had acquired the conviction that there are few subjects respecting which it is more important for all classes of the community to have clear and just ideas than this, while certainly there is none which is more deserving of attention by the Working-Men's Club and Institute Union.

It is not for me to express an opinion whether the considerations which I am about to submit to you will be proved by experience to be just or not; but I will do my best to make them clear. Among the many good things to be found in Lord Bacon's works, none is more full of wisdom than the saying that "truth more easily comes out of error than out of confusion." Clear and consecutive wrong-thinking is the next best thing to right-thinking; so that, if I succeed in clearing your ideas on this topic, I shall have wasted neither your time nor my own.

"Technical education," in the sense in which the term is ordinarily used, and in which I am now employing it, means that sort of education which is specially adapted to the needs of men whose business in life it is to pursue some kind of handicraft; it is, in fact, a fine Greco-Latin equivalent for what in good vernacular English would be called "the teaching of handicrafts." And probably, at this stage of our progress, it may occur to many of you to think of the story of the cobbler and his last, and to say to yourselves, though you will be too

[1] An address delivered to the Working-Men's Club and Institute Union, December, 1, 1877.

polite to put the question openly to me: "What does the speaker know practically about this matter? What is his handicraft?" I think the question is a very proper one, and, unless I were prepared to answer it, I hope satisfactorily, I should have chosen some other theme.

The fact is, I am, and have been any time these thirty years, a man who works with his hands—a handicraftsman. I do not say this in the broadly metaphorical sense in which fine gentlemen, with all the delicacy of Agag about them, trip to the hustings about election-time, and protest that they, too, are working-men. I really mean my words to be taken in their direct, literal, and straightforward sense. In fact, if the most nimble-fingered watchmaker among you will come to my workshop, he may set me to put a watch together, and I will set him to dissect, say, a black-beetle's nerves. I do not wish to vaunt, but I am inclined to think that I shall manage my job to his satisfaction sooner than he will do his piece of work to mine.

In truth, anatomy, which is my handicraft, is one of the most difficult kinds of mechanical labor, involving, as it does, not only lightness and dexterity of hand, but sharp eyes and endless patience. And you must not suppose that my particular branch of science is especially distinguished for the demand it makes upon skill in manipulation. A similar requirement is made upon all students of physical science. The astronomer, the electrician, the chemist, the mineralogist, the botanist, are constantly called upon to perform manual operations of exceeding delicacy. The progress of all branches of physical science depends upon observation, or on that artificial observation which is termed experiment, of one kind or another; and the further we advance the more practical difficulties surround the investigation of the conditions of the problems offered to us; so that mobile and yet steady hands, guided by clear vision, are more and more in request in the workshops of science.

Indeed, it has struck me that one of the grounds of that sympathy between the handicraftsmen of this country and the men of science, by which it has so often been my good fortune to profit, may, perhaps, lie here. You feel and we feel that, among the so-called learned folks, we alone are brought into contact with tangible facts in the way that you are. You know well enough that it is one thing to write a history of chairs in general, or to address a poem to a throne, or to speculate about the occult powers of the chair of St. Peter; and quite another thing to make with your own hands a veritable chair, that will stand fair and square, and afford a safe and satisfactory resting-place to a frame of sensitiveness and solidity.

So it is with us, when we look out from our scientific handicrafts upon the doings of our learned brethren, whose work is untrammeled by anything "base and mechanical," as handicrafts used to be called when the world was younger, and, in some respects, less wise than

now. We take the greatest interest in their pursuits; we are edified by their histories and are charmed with their poems, which sometimes illustrate so remarkably the powers of man's imagination; some of us admire and even humbly try to follow them in their high philosophical excursions, though we know the risk of being snubbed by the inquiry whether groveling dissectors of monkeys and black-beetles can hope to enter into the empyreal kingdom of speculation. But still we feel that our business is different; humbler if you will, though the diminution of dignity is, perhaps, compensated by the increase of reality; and that we, like you, have to get our work done in a region where little avails, if the power of dealing with practical, tangible facts is wanting. You know that clever talk touching joinery will not make a chair; and I know that it is of about as much value in the physical sciences. Mother Nature is serenely obdurate to honeyed words; only those who understand the ways of things, and can silently and effectually handle them, get any good out of her.

And now, having, as I hope, justified my assumption of a place among handicraftsmen, and put myself right with you as to my qualification, from practical knowledge, to speak about technical education, I will proceed to put before you the results of my experience as a teacher of a handicraft, and tell you what sort of education I should think best adapted for a boy whom one wanted to make a professional anatomist.

I should say, in the first place, let him have a good English elementary education. I do not mean that he shall be able to pass in such and such a standard—that may or may not be an equivalent expression—but that his teaching shall have been such as to have given him command of the common implements of learning and created a desire for the things of the understanding.

Further, I should like him to know the elements of physical science, and especially of physics and chemistry, and I should take care that this elementary knowledge was real. I should like my aspirant to be able to read a scientific treatise in Latin, French, or German, because an enormous amount of anatomical knowledge is locked up in those languages. And especially I should require some ability to draw —I do not mean artistically, for that is a gift which may be cultivated but cannot be learned, but with fair accuracy. I will not say that everybody can learn even this; for the negative development of the faculty of drawing in some people is almost miraculous. Still everybody, or almost everybody, can learn to write; and, as writing is a kind of drawing, I suppose that the majority of the people who say they cannot draw, and give copious evidence of the accuracy of their assertion, could draw, after a fashion, if they tried. And that "after a fashion" would be better than nothing for my purposes.

Above all things, let my imaginary pupil have preserved the

freshness and vigor of youth in his mind as well as his body. The educational abomination of desolation of the present day is the stimulation of young people to work at high pressure by incessant competitive examinations. Some wise man (who probably was not an early riser) has said of early risers in general, that they are conceited all the forenoon and stupid all the afternoon. Now, whether this is true of early risers in the common acceptation of the word or not, I will not pretend to say; but it is too often true of the unhappy children who are forced to rise too early in their classes. They are conceited all the forenoon of life, and stupid all its afternoon. The vigor and freshness, which should have been stored up for the purposes of the hard struggle for existence in practical life, have been washed out of them by precocious mental debauchery—by book-gluttony and lesson-bibbing. Their faculties are worn out by the strain put upon their callow brains, and they are demoralized by worthless childish triumphs before the real work of life begins. I have no compassion for sloth, but youth has more need for intellectual rest than age; and the cheerfulness, the tenacity of purpose, the power of work which make many a successful man what he is, must often be placed to the credit, not of his hours of industry, but to that of his hours of idleness, in boyhood. Even the hardest worker of us all, if he has to deal with anything above mere details, will do well, now and again, to let his brain lie fallow for a space. The next crop of thought will certainly be all the fuller in the ear and the weeds fewer.

This is the sort of education which I should like any one who was going to devote himself to my handicraft to undergo. As to knowing anything about anatomy itself, on the whole I would rather he left that alone until he took it up seriously in my laboratory. It is hard work enough to teach, and I should not like to have superadded to that the possible need of unteaching.

Well, but, you will say, this is Hamlet with the Prince of Denmark left out; your "technical education" is simply a good education, with more attention to physical science, to drawing, and to modern languages, than is common, and there is nothing specially technical about it.

Exactly so; that remark takes us straight to the heart of what I have to say, which is, that, in my judgment, the preparatory education of the handicraftsman ought to have nothing of what is ordinarily understood by "technical" about it.

The workshop is the only real school for a handicraft. The education which precedes that of the workshop should be entirely devoted to the strengthening of the body, the elevation of the moral faculties, and the cultivation of the intelligence; and especially to the imbuing the mind with a broad and clear view of the laws of that natural world with the components of which the handicraftsman will have to deal. And the earlier the period of life at which the handicraftsman has to

enter into actual practice of his craft, the more important is it that he should devote the precious hours of preliminary education to things of the mind, which have no direct and immediate bearing on his branch of industry, though they lie at the foundation of all realities.

Now let me apply the lessons I have learned from my handicraft to yours. If any of you were obliged to take an apprentice, I suppose you would like to get a good, healthy lad, ready and willing to learn, handy, and with his fingers not all thumbs, as the saying goes. You would like that he should read, write, and cipher well; and, if you were an intelligent master, and your trade involved the application of scientific principles, as so many trades do, you would like him to know enough of the elementary principles of science to understand what was going on. I suppose that in nine trades out of ten it would be useful if he could draw; and many of you must have lamented your inability to find out for yourselves what foreigners are doing or have done. So that some knowledge of French and German might, in many cases, be very desirable.

So it appears to me that what you want is pretty much what I want; and the practical question is, How you are to get what you need, under the actual limitations and conditions of life of handicraftsmen in this country?

I think I shall have the assent both of the employers of labor and of the employed as to one of these limitations; which is, that no scheme of technical education is likely to be seriously entertained which will delay the entrance of boys into working-life, or prevent them from contributing toward their own support, as early as they do at present. Not only do I believe that any such scheme could not be carried out, but I doubt its desirableness, even if it were practicable.

The period between childhood and manhood is full of difficulties and dangers, under the most favorable circumstances; and even among the well-to-do, who can afford to surround their children with the most favorable conditions, examples of a career ruined, before it has well begun, are but too frequent. Moreover, those who have to live by labor must be shaped to labor early. The colt that is left at grass too long makes but a sorry draught-horse, though his way of life does not bring him within the reach of artificial temptations. Perhaps the most valuable result of all education is the ability to make yourself do the thing you have to do, when it ought to be done, whether you like it or not; it is the first lesson that ought to be learned; and, however early a man's training begins, it is probably the last lesson that he learns thoroughly.

There is another reason to which I have already adverted, and which I would reiterate, why any extension of the time devoted to ordinary school-work is undesirable. In the newly-awakened zeal for education, we run some risk of forgetting the truth that, while un-

der-instruction is a bad thing, over-instruction may possibly be a worse.

Success in any kind of practical life is not dependent solely, or indeed chiefly, upon knowledge. Even in the learned professions knowledge, alone, is of less consequence than people are apt to suppose. And, if much expenditure of bodily energy is involved in the day's work, mere knowledge is of still less importance when weighed against the probable cost of its acquirement. To do a fair day's work with his hands, a man needs, above all things, health, strength, and the patience and cheerfulness which, if they do not always accompany these blessings, can hardly in the nature of things exist without them; to which we must add honesty of purpose and a pride in doing what is done well.

A good handicraftsman can get on very well without genius, but he will fare badly without a reasonable share of what is a more useful possession for work-a-day life, namely, mother-wit; and he will be all the better for a real knowledge, however limited, of the ordinary laws of Nature, and especially of those which apply to his own business.

Instruction carried so far as to help the scholar to turn his store of mother-wit to account, to acquire a fair amount of sound elementary knowledge, and to use his hands and eyes, while leaving him fresh, vigorous, and with a sense of the dignity of his own calling, whatever it may be, if fairly and honestly pursued, cannot fail to be of invaluable service to all those who come under its influence.

But, on the other hand, if school instruction is carried so far as to encourage bookishness; if the ambition of the scholar is directed, not to the gaining of knowledge, but to the being able to pass examinations successfully; especially if encouragement is given to the mischievous delusion that brain-work is, in itself, and apart from its quality, a nobler or more respectable thing than handiwork—such education may be a deadly mischief to the workman, and lead to the rapid ruin of the industries it is intended to serve.

I know that I am expressing the opinion of some of the largest as well as the most enlightened employers of labor, when I say that there is a real danger that, from the extreme of no education, we may run to the other extreme of over-education of handicraftsmen. And I apprehend that what is true for the ordinary hand-worker is true for the foreman. Activity, probity, knowledge of men, ready mother-wit, supplemented by a good knowledge of the general principles involved in his business, are the making of a good foreman. If he possess these qualities, no amount of learning will fit him better for his position; while the course of life and the habit of mind required for the attainment of such learning may, in various direct and indirect ways, act as direct disqualifications for it.

Keeping in mind, then, that the two things to be avoided are, the delay of the entrance of boys into practical life, and the substitution

of exhausted bookworms for shrewd, handy men in our works and factories, let us consider what may be wisely and safely attempted in the way of improving the education of the handicraftsman.

First, I look to the elementary schools now happily established all over the country. I am not going to criticise or find fault with them; on the contrary, their establishment seems to me to be the most important and the most beneficent result of the corporate action of the people in our day. A great deal is said of British interests just now, but, depend upon it, that no Eastern difficulty needs our intervention as a nation so seriously as the putting down both the Bashi-Bazouks of ignorance and the Cossacks of sectarianism at home. What has already been achieved in these directions is a great thing; you must have lived some time to know how great. An education, better in its processes, better in its substance, than that which was accessible to the great majority of well-to-do Britons a quarter of a century ago, is now obtainable by every child in the land. Let any man of my age go into an ordinary elementary school, and, unless he was unusually fortunate in his youth, he will tell you that the educational method, the intelligence, patience, and good temper, on the teachers' part, which are now at the disposal of the veriest waifs and wastrels of society, are things of which he had no experience in the costly middle-class schools; which were so ingeniously contrived as to combine all the evils and shortcomings of the great public schools with none of their advantages. Many a man, whose so-called education cost a good deal of valuable money and occupied many a year of invaluable time, leaves the inspection of a well-ordered elementary school devoutly wishing that, in his young days, he had had the chance of being as well taught as these boys and girls are.

But while, in view of such an advance in general education, I willingly obey the natural impulse to be thankful, I am not willing altogether to rest. I want to see instruction in elementary science and in art more thoroughly incorporated in the educational system. At present, it is being administered by driblets, as if it were a potent medicine, "a few drops to be taken occasionally in a teaspoon." Every year I notice that that earnest and untiring friend of yours and of mine, Sir John Lubbock, stirs up the government of the day in the House of Commons on this subject; and also that, every year, he, and the few members of the House of Commons, such as Mr. Playfair, who sympathize with him, are met with expressions of warm admiration for science in general, and reasons at large for doing nothing in particular. But now that Mr. Forster, to whom the education of the country owes so much, has announced his conversion to the right faith, I begin to hope that, sooner or later, things will mend.

I have given what I believe a good reason for the assumption that the keeping at school of boys who are to be handicraftsmen beyond the age of thirteen or fourteen is neither practicable nor desirable;

and as it is quite certain that, with justice to other and no less important branches of education, nothing more than the rudiments of science and art teaching can be introduced into elementary schools, we must seek elsewhere for a supplementary training in these subjects, and, if need be, in foreign languages, which may go on after the workman's life has begun.

The means of acquiring the scientific and artistic part of this training already exists in full working order, in the first place, in the classes of the Science and Art Department, which are for the most part held in the evening, so as to be accessible to all who choose to avail themselves of them after working-hours. The great advantage of these classes is that they bring the means of instruction to the doors of the factories and workshops; that they are no artificial creations, but by their very existence prove the desire of the people for them; and, finally, that they admit of indefinite development in proportion as they are wanted. I have often expressed the opinion, and I repeat it here, that, during the eighteen years they have been in existence, these classes have done incalculable good; and I can say, of my own knowledge, that the department spares no pains and trouble in trying to increase their usefulness and insure the soundness of their work.

No one knows better than my friend Colonel Donnelly, to whose clear views and great administrative abilities so much of the successful working of the science classes is due, that there is much to be done before the system can be said to be thoroughly satisfactory. The instruction given needs to be made more systematic, and especially more practical; the teachers are of very unequal excellence, and not a few stand much in need of instruction themselves, not only in the subjects which they teach, but in the objects for which they teach. I dare say you have heard of that proceeding, reprobated by all true sportsmen, which is called "shooting for the pot." Well, there is such a thing as "teaching for the pot"—teaching, that is, not that your scholar may know, but that he may count for payment among those who pass the examination; and there are some teachers, happily not many, who have yet to learn that the examiners of the department regard them as poachers of the worst description.

Without presuming in any way to speak in the name of the department, I think I may say, as a matter which has come under my own observation, that it is doing its best to meet all these difficulties. It systematically promotes practical instruction in the classes; it affords facilities to teachers who desire to learn their business thoroughly; and it is always ready to aid in the suppression of pot-teaching.

All this is, as you may imagine, highly satisfactory to me. I see that spread of scientific education, about which I have so often permitted myself to worry the public, become, for all practical purposes,

an accomplished fact. Grateful as I am for all that is now being done, in the same direction, in our higher schools and universities, I have ceased to have any anxiety about the wealthier classes. Scientific knowledge is spreading by what the alchemists called a "distillatio per ascensum;" and nothing now can prevent it from continuing to distill upward and permeate English society, until, in the remote future, there shall be no member of the Legislature who does not know as much of science as an elementary schoolboy; and even the heads of houses in our venerable seats of learning shall acknowledge that natural science is not merely a sort of university back-door, through which inferior men may get at their degrees. Perhaps this apocalyptic vision is a little wild; and I feel I ought to ask pardon for an outbreak of enthusiasm, which, I assure you, is not my commonest failing.

I have said that the Government is already doing a great deal in aid of that kind of technical education for handicraftsmen which, to my mind, is alone worth seeking. Perhaps it is doing as much as it ought to do, even in this direction. Certainly there is another kind of help of the most important character, for which we may look elsewhere than to the Government. The great mass of mankind have neither the liking, nor the aptitude, for either literary, or scientific, or artistic, pursuits; nor, indeed, for excellence of any sort. Their ambition is to go through life with moderate exertion and a fair share of ease, doing common things in a common way. And a great blessing and comfort it is that the majority of men are of this mind; for the majority of things to be done are common things, and are quite well enough done when commonly done. The great end of life is not knowledge, but action. What men need is as much knowledge as they can assimilate and organize into a basis for action; give them more and it may become injurious. One knows people who are as heavy and stupid from undigested learning as others are from over-fullness of meat and drink. But a small percentage of the population is born with that most excellent quality, a desire for excellence, or with special aptitudes of some sort or another; Mr. Galton tells us that not more than one in four thousand may be expected to attain distinction, and not more than one in a million some share of that intensity of instinctive aptitude, that burning thirst for excellence, which is called genius.

Now, the most important object of all educational schemes is to catch these exceptional people and turn them to account for the good of society. No man can say where they will crop up; like their opposites, the fools and knaves, they appear sometimes in the palace and sometimes in the hovel; but the great thing to be aimed at, I was almost going to say the most important end of all social arrangements, is to keep these glorious sports of Nature from being either corrupted by luxury or starved by poverty, and to put them into the

position in which they can do the work for which they are specially fitted.

Thus, if a lad in an elementary school showed signs of special capacity, I would try to provide him with the means of continuing his education after his daily working-life had begun; if, in the evening classes, he developed special capabilities in the direction of science or of drawing, I would try to secure him an apprenticeship to some trade in which those powers would have applicability. Or, if he chose to become a teacher, he should have the chance of so doing. Finally, to the lad of genius, the one in a million, I would make accessible the highest and most complete training the country could afford. Whatever that might cost, depend upon it the investment would be a good one. I weigh my words when I say that, if the nation could purchase a potential Watt, or Davy, or Faraday, at the cost of a hundred thousand pounds down, he would be dirt-cheap at the money. It is a mere commonplace and every-day piece of knowledge, that what these three men did has produced untold millions of wealth, in the narrowest economical sense of the word.

Therefore, as the sum and crown of what is to be done for technical education, I look to the provision of a machinery for winnowing out the capacities and giving them scope. When I was a member of the London School Board, I said, in the course of a speech, that our business was to provide a ladder, reaching from the gutter to the university, along which every child in the three kingdoms should have the chance of climbing as far as he was fit to go. This phrase was so much bandied about at the time, that, to say truth, I am rather tired of it; but I know of no other which so fully expresses my belief, not only about education in general, but about technical education in particular.

The essential foundation of all the organization needed for the promotion of education among handicraftsmen will, I believe, exist in this country when every working-lad can feel that society has done what lies in its power to remove all needless and artificial obstacles from his path; that there is no barrier, except such as exist in the nature of things, between himself and whatever place in the social organization he is fitted to fill; and, more than this, that, if he has capacity and industry, a hand is held out to help him along any path which is wisely and honestly chosen.

I have endeavored to point out to you that a great deal of such an organization already exists; and I am glad to be able to add that there is a good prospect that what is wanting will, before long, be supplemented.

Those powerful and wealthy societies, the livery companies of the city of London, remembering that they are the heirs and representatives of the trade-guilds of the middle ages, are interesting themselves in the question. So far back as 1872 the Society of Arts or-

ganized a system of instruction in technology of arts and manufactures, for persons actually employed in factories and workshops, who desired to extend and improve their knowledge of the theory and practice of their particular avocations;[1] and a considerable subsidy was liberally granted in aid of the efforts of the Society by the Cloth-workers' Company. We have here the hopeful commencement of a rational organization for the promotion of excellence among handicraftsmen. Quite recently other of the livery companies have determined upon giving their powerful and, indeed, almost boundless aid to the improvement of the teaching of handicrafts. They have already gone so far as to appoint a committee to act for them; and I betray no confidence in adding that, some time since, the committee sought the advice and assistance of several persons, myself among the number.

Of course, I cannot tell you what may be the result of the deliberations of the committee; but we may all fairly hope that, before long, steps which will have a weighty and a lasting influence on the growth and spread of sound and thorough teaching among the handicraftsmen[2] of this country will be taken by the livery companies of London. —*Fortnightly Review.*

THE DEBASEMENT OF COINAGES.

By E. R. LELAND.

IN primitive days the parties to a trade had in every case first to agree as to the quantity and quality of the articles to be exchanged. When gold and silver first made their appearance in the list of commodities they were, along with other metals, in an unfashioned state, and the processes of barter were carried on with them precisely as with more bulky and inconvenient articles, so that at each transfer it became necessary to determine their quality and quantity, that is, their purity and weight, by the crude methods which then obtained. Such is still the case among some of the far-away, half-civilized nations, and in the early days of California and Australia gold-digging, "nuggets" and "dust" were in common use as currency.

With all the perfection of modern scientific appliances the work of assaying is one of great difficulty and nicety, and it must have been impossible for primitive merchants to reach anything but the rudest approximations. To do even this involved a great deal of trouble and loss of time, so that the necessity of devising some means by which

[1] *See* the "Programme" for 1878, issued by the Society of Arts, p. 14.

[2] It is perhaps advisable to remark that the important question of the professional education of managers of industrial works is not touched in the foregoing remarks.

the weight and fineness of a piece of gold or silver could be easily determined was early felt.

The first forms which could be called by the name of money were ingots in various shapes, stamped or sealed with the seal of the ruler as a certificate of the quality and weight of the piece, no attempt being made to so fashion the coin as to guard against alteration of weight. Some of the early pieces were stamped on but one side, and it was only by very gradual steps that the handsome circular pieces which we know as coins were evolved. But these are still defined by Jevons as "*ingots*, of which the weight and fineness are certified by the integrity of the designs impressed upon the surface of the metal."

The stamping of the bits of metal has always been assumed as a prerogative of the ruler, and to supply the people with coin has come to be generally considered a function of government. It will be well to bear the above definition of coin in mind; for the fashioning, stamping, and certification, have often caused a very important fact to be lost sight of, which is, that throughout these changes the metals continue to be commodities and nothing more. The stamp works no alteration in the metal, any more than does the label on a bolt of muslin, showing the width and the number of yards, convert it into something other than cotton cloth. The conversion of the unfashioned metal into coin in no way affects the principle of exchanges, and its transfer is barter just as much as it was in the beginning.

Coins command other commodities by the amount of pure metal in them.

The silver dollar buys just as much food or clothing as would so many grains of silver in any other shape; and the stamp—whether it show the classical features of Kaiser William or the graceful figure of the Goddess of Liberty—does not increase its purchasing power, except to the very slight degree which is the measure of the convenience of having it converted from bullion into coin at public cost, but this percentage is so small that it may for present purposes be neglected.

But it has come about that, instead of being looked upon as simply certified bullion, coin is frequently regarded as something mysterious in its nature and function.

Gold and silver, from their physical properties, are the most fit of all known substances for mediums of exchange. From their general use as money they are commonly spoken of as measures of value, and there is no objection to this expression if it be understood to mean that they constitute a term or factor constantly used in arriving at the ratio which exists between the various articles of commerce; but it should be remembered that this factor is not constant, though for purposes of convenience it is generally assumed to be so. As a matter of fact, gold and silver measure the value of commodities in precisely the same way that the commodities measure the value of gold

and silver. Value is based on utility, but utility is not intrinsic in any substance; and a thing is only useful so far as it is supplied in needful quantities at the right time, the degree of utility constantly varying. And so, although we may get the value of x (gold and silver) in terms of y (other commodities), and the value of y in terms of x, both x and y remain unknown and variable quantities, however glibly we may talk about them.

Although the same difficulty confronts us here that is met in all attempts at the ultimate analysis of things, none the less is it imperative that there should be a fixity of standards, rigidly adhered to. To define a pound avoirdupois is as difficult as to define a pound sterling; but commerce and science are alike dependent upon absolute adherence to certain standards of weight, and upon the assumption that the law of gravitation, by which weight is determined, is inflexible.

Until the indestructibility of matter and the persistence of force were demonstrated, there was nothing absurd in the supposition that matter could be created and annihilated, force produced and destroyed; and men of genius and learning vainly sought to turn dross to gold, to find the elixir of life, to construct machines which should create their own force. Modern chemistry has dispelled the dreams of the alchemist; physiology has determined the laws of waste and supply and fixed pretty definitely the limitations of life; and the discoveries of Meyer and Joule have shown the fallacy of perpetual motion. These things are now pretty generally understood, although a lunatic is still occasionally to be found who wastes his life because of his inability to comprehend them: but it is not so generally recognized that the principle of the correlation of forces is universal; that it applies rigidly to all human activities; and that it is quite as impossible in economical dynamics as elsewhere to get something for nothing.

That coins are simply stamped bullion, and that the purchasing power of money is regulated by the quantity of pure metal only is now conceded by all economic writers; but the establishment of this principle is comparatively recent. In early times most extraordinary delusions prevailed on this subject, nor are they yet wholly dissipated. It will be interesting and instructive to note some of the mutations which have been caused in the world's coinage by the numerous royal and legislative attempts to make a part equal to the whole.

The coins of all countries seem to have been called by the same name as the weights used in them, and to have originally contained the quantity of metal indicated by their names. The coins used in Greece, Italy, France, and England, weighed in the first instance just a *talent*, an *as*, or *pond*, a *livre*, or a *pound*.

The Roman *as*, or *libra*, at first contained twelve ounces of copper, and was divided into twelve parts or *unciæ*, a division which was maintained for a long time. It is not known who first falsified the certifi-

cate and gained an illusory augmentation of wealth by reducing the weight of metal in the *as*, still calling it by the same name. But this fraudulent plan, once adopted, was worked with such assiduity by the successive emperors, that in 175 B. C. the *as* contained but half an ounce of copper, or $\frac{1}{24}$ part of its original weight. In the case of so cheap a metal, diminishing the quantity was the only way in which the coin could be degraded. The principal silver coin was the *denarius*, rated at ten *asses*, and weighing one-seventh of an ounce. Its weight was tolerably well maintained, but adulteration was carried to its utmost extent, and eventually the imperial *denarii* came to be only copper coins plated with silver! Similar vicissitudes marked the career of Roman gold. When first coined, 204 B. C., the *aureus* weighed $\frac{1}{40}$ part of a pound of pure gold, but through various degradations came to be only $\frac{1}{72}$ part of a pound in weight, and this bore 20 per cent. of alloy.

The French money-unit, the *livre*, up to the reign of Charlemagne, contained exactly a pound weight of pure silver, and was divided into 20 *sols*. It was reserved for Philip I. to violate this standard. He considerably diminished the amount of silver contained in a *sol*, and his example was followed with such zeal that by the time of the Revolution the *livre* contained less than a seventy-eighth part of the silver which it had in the eleventh century.

Nor is this an extreme case. In 1220 the Spanish *maravedi* weighed 84 grains of gold, and was equal in value to about $3.50; it descended until it became a small copper coin valued at one-third of a cent.

The German *florin* was originally a gold coin worth $2.50; when abolished it was 40 cents' worth of silver.

These examples are taken from the history of the most stable and best-governed European states, and from them may be inferred the rapacity and swindling of the lawless, irresponsible feudal princes during the middle ages, which caused this particular fraud to fall into the deepest discredit even in those early days.

The Chinese probably illustrate in the most extreme manner the length to which loose views concerning currency can be carried. The history of their currency presents that mingling of the grotesque with the tragic which most of their actions have when viewed through Western eyes. Coined money was known among them as early as the eleventh century before Christ, but their inability to comprehend the principles upon which a currency should be based has led them into all sorts of extravagances, which have been attended by disorder, famine, and bloodshed. Coins came at last to be made so thin that 1,000 of them piled together were only three inches high; then gold and silver were abandoned; and copper, tin, shells, skins, stones, and paper, were given a fixed value, and used until, by abuse, all the advantages to be derived from the use of money were lost, and there

was nothing left for the people to do but to go back to barter, and this they did more than once. They cannot be said now to have a coinage; 2,900 years ago they made round coins with a square hole in the middle, and they have made no advance beyond that since. The well-known *cash* is a cast-brass coin of that description, and, although it is valued at about one mill and a half of our money, and has to be strung in lots of 1,000 to be computed with any ease, it is the sole measure of value and legal tender of the country. Spanish, Mexican, and our new trade-dollars, are employed in China; they pass because they are necessary for larger operations, and because faith in their standard value has become established; but they are current simply as stamped ingots, with their weight and fineness indicated.

The coinage of England, although it has suffered less than that of any of the older countries, has still undergone great debasement, which has begotten misery and trouble enough to make her experience of great value. At the time of the Norman Conquest the silver or money pound weighed 12 ounces, the system of coinage being the same as that of Charlemagne, and it was continued untouched until the year 1300, when the standard was tampered with by Edward I. By increasing the number of shillings made from a pound, he set a pernicious example which was followed only too well, so that in the reign of Queen Elizabeth 58 shillings instead of 20 shillings were coined out of the pound weight of silver. Up to the reign of Henry VIII., although the weight was decreased, the sterling fineness of coins was not debased; but that eminent head of the Church, after dissipating the immense wealth which he received from his father, resorted to the most disgraceful means to supply his riot and extravagance. He so adulterated and degraded the silver coinage that the pound sterling contained but four ounces of silver, £2 8*s*. of it being equivalent to the pound sterling of 500 years before. Under the reigns of his children, Edward VI., Mary, and Elizabeth, the fineness of the coin was gradually restored, and its degradation arrested, so that it was the boast of Elizabeth that she "had conquered now that monster which so long had devoured her people." The coinage of England has had nothing further to endure at the hands of her princes.

The reign of James II., bad enough in all ways, was in no instance more disgraceful than the state to which he brought the coinage of Ireland during his brief kingship there. His coins of gun-metal, copper, brass, pewter, the sorriest tokens, were made unlimited tender, and forced into circulation by every device. His loyal Irish subjects were the sufferers from this swindle, for they had in their possession nearly the whole of his worthless money. As he was compelled to abandon England before his necessities became very great, her money escaped violation.

Of course, all this tampering with money has been accompanied

by tyrannical laws which were intended to make the debased coin pass for just as much as the pure. Nothing would be gained unless this could be done. Mint-officers were sworn to secrecy, but the melting-pot revealed the fraud. Proclamations were issued by Edward II., commanding, under heavy penalties, that the money should be kept current at the stamped value, and that no one should enhance the price of his goods on that account, for it was the king's pleasure that the coins should be kept up to the same value they were wont to bear! Later, in the reign of Edward VI., when the debasement reached its lowest depths, a *maximum* was set on the price of corn, and those who refused to carry their grain to market were to be punished.

Absurd as such compulsory laws may seem to us, they are perfectly logical outcomes of any attempts to lower the standard of money. There is nothing to be gained by debasing coinage unless the operations of commerce can be regulated upon the assumption that a part *is* equal to the whole. Edward's proclamation, that it was his pleasure that the coins should be kept up to the value that they were wont to bear, and that people should be compelled to market their goods at the old prices, was more difficult of enforcement, but not different in principle, no whit more dishonest, than a law which shall make 90 cents a legal tender for 100, in the discharge of all debts.

It was hardly to be expected that a higher standard of morality would be found among subjects than that held to by their rulers. The tampering was begun by the people on their own account, the more readily as the nature of the coin made this an easy matter. In making the coins the metal was divided with shears, and afterward shaped and stamped by hand with the hammer. They were not exact in size or weight: some contained more, and some less, than the correct quantity of silver; few pieces were exactly round; and, as the edges were smooth, nothing was easier than to take a slight paring from the pieces as they passed from hand to hand.

Coin-clipping was discovered to be profitable and comparatively safe, and it was practised with great industry. As early as the reign of Elizabeth it was prohibited, on the pain of life and limb, and the forfeiture of all lands. But the practice was too lucrative to be thus checked, and by the time of the Restoration the larger part of the silver in circulation was mutilated. Macaulay has described in most graphic manner this episode in the history of British coinage. All trade and industry was deranged by the confusion which arose from the disgraceful state of the money. "Nothing could be purchased without a dispute. Over every counter there was wrangling from morning till night. The workman and his employer had a quarrel as regularly as the Saturday came round."

Guineas, which had originally been coined to be equal to 20*s.*, rose as the silver grew worse, till they were current at 30*s.* of the base trash which passed by the name of silver coin. The shrinkage on the

average of the pieces in circulation amounted to nearly or quite 50 per cent. The most rigorous and cruel laws were passed, but they were ineffectual, and, while scores of miserable wretches were dangling from the gibbets, clipping was as rife as ever.

Clipping is here referred to at some length, because it differs from other degradations of coinage only in respect to the parties by whom it is done. It is reducing the value of coin without public authority, and is the least mischievous of the two forms, because, as no one is compelled to take clipped coins, the loss is forced on no one.

The first effort to correct the evils which had thus arisen was, by furnishing a large supply of fresh, honest, milled coins. The politicians of that day believed that, if the people were given plenty of new and good money, it would soon displace the old; and so the mints were run to their utmost capacity, but the new coins vanished from sight as fast as they were put ont. Gresham's law, that "bad money drives out good money, but that good money cannot drive out bad money," although not then formulated, worked its inevitable result. The statesmen marveled that men would not pay 12 ounces of silver when 10 could be made to serve the purpose, but they persistently refused to do so. By the time of William III., the necessity of resorting to some measures which should be effectual was generally felt.

It was evident to all that the old coinage must in some way be supplanted by a new, but the manner in which this should be done was warmly disputed. Mr. William Lowndes, then Secretary of the Treasury, was ordered to make a report and did so, recommending that the standard of the new coin should be depreciated to the level of the trash in circulation, by making the new shilling worth ninepence or thereabouts. He asserted, and attempted to prove, "that making the pieces less, or ordaining the respective pieces (of the present weight) to be current at a higher rate, might equally raise the value of silver in our coins;" and seriously argued that, if an ounce of silver were but cut up finer, other nations would be induced to sell their products for a smaller number of ounces. He had a considerable following, composed, Macaulay says, "partly of dull men who really believed what he told them, and partly of shrewd men who were perfectly willing to be authorized by law to pay a hundred pounds with eighty"—a description which fits with sufficient accuracy the advocates of the Bland Bill.

Lowndes's fallacies were exposed with great ability by Locke, and fortunately wiser counsels prevailed. The old standard was maintained in the new issues, and the clipped coins were called in, the loss falling, as it should do, on the public at large. Space forbids the introduction here of the arguments by which this wise course was sustained. The controversy is interesting and instructive, and deserves attention, for it was revived 116 years later when Bank-of-England

notes became depreciated, and is raging now that silver has undergone a similar decline. It is true that the situation is not precisely the same, but the principle involved is: the arguments against restoring a degraded coinage or degrading an established one are substantially the same.

The object of the Bland Bill and similar measures, though nominally a restoration of a former standard, is in fact a debasement of the present one. The value fixed for the United States dollar under the act of 1792 was by accident put below that of the dollars with which it then came into competition. The act provided that the dollar should be of the value of the Spanish milled dollar, and also provided that it should contain 371¼ grains of pure silver, whereas the Spanish dollar contained 377¼ grains. This discrepancy resulted from a blunder in assaying the Spanish coin, but was perpetuated until the old silver dollar was abolished. Owing to the unprecedented fall in the price of silver, the real value of 371¼ grains is now only about ninety cents in the market, a decline which would be a very serious matter if this accidental dollar were still a legal tender and in use in trade; but fortunately the act of 1873 put it where it is incapable of doing mischief.

It is one of the compensations of the disordered state of our finances growing out of irredeemable war-issues, that, coin being virtually out of circulation, we could put our coinage on the footing aimed at by all great commercial nations, without incurring the loss and distress which such revolutions are apt to involve. And now it is proposed to undo all this, to restore this impaired dollar to its old position, and put upon the nation all the loss and inconvenience which would grow out of such a change. For states of transition are always states of suffering and, were there two or three hundred millions of silver in the hands of the people to-day, the statesman well might hesitate to raise the standard of the old dollar, making it equivalent to the gold one. The load of silver which France is carrying interferes seriously with her efforts to resume on her paper currency, and yet she very properly hesitates to enter upon an experience similar to that which Germany has recently had; but we, virtually starting anew with our coinage system, with the experience of all the past to light us, are asked to plunge into a quagmire from which we could only emerge after much floundering and defilement!

And who is to be benefited by the remonetization of silver? If remonetization will, as is claimed for it, enhance the price of silver, so that it will make the dollar of 1792 and the gold dollar equal, then the holders of silver and they only will reap the advantage. Is the disposable silver stock of the world held by the class of men into whose pockets the Western voters are anxious to legislate money? The American mine-owners hold a large amount in the shape of ore; the German Empire has ninety millions of surplus she would be glad

to dispose of; the Bank of France has one hundred and forty odd millions in its vaults, that is a source of great present disquietude; England has a fair stock, and as creditor of India is likely to become the holder of much more; she is deeply interested in seeing the price of silver sustained, and would be very grateful for relief from any quarter. It is from these sources the silver would flow if the United States should decide to assume the function of pulling chestnuts for the entire commercial world, and these are the men who would profit by remonetization—provided that step should have the effect on the price of silver that is claimed for it. But the assumption that it will bring the gold and silver dollar upon a par is entirely unwarranted.

The Monetary Commission, of which Mr. Jones was chairman and Mr. Bland a member, are at great pains to show, in their report, that, owing to the magnitude of the stocks of silver and gold in the world, the value of the precious metals cannot be visibly affected by current production; that no current supply was ever yet sufficiently great to affect the value of the metals except slowly and by almost imperceptible degrees. This may or may not be so, but it is a little curious to note that the same gentlemen who in their report maintained that the effect of an annual *supply* of $65,000,000 or $70,000,000 would have no appreciable effect on the price of silver, are now gravely arguing that an annual *demand* of say $25,000,000—the utmost capacity of our mints—would at once enhance the price by 10 per cent. Here they forget the insignificance of the amount in comparison with the enormous accumulated stock of the world.

A further decline in the price of silver is far more probable than an advance, and it is only because the old silver dollar is worth but 90 cents, and likely to be worth less rather than more, that it is so loudly clamored for. The avowed object of its restoration is to relieve those who have debts to pay.

Neither in motive nor in method does this differ from the disreputable frauds of the feudal princes who adulterated their coins that they might pay their debts more easily. Both the act and its consequences are identical. The image and the superscription of the monarch lied in the older example: in the modern instance the image and the superscription are no less lying ones. And the consequences will in no wise differ. Henry VIII. was enabled to cheat his creditors in precisely the same unscrupulous way that is proposed for the United States to cheat theirs, by paying them in coins of diminished value; and the losses he entailed upon his subjects—far exceeding his own gains—were precisely those we should suffer. All creditors are placed in the position of the creditors of the swindling government. Debtors are indiscriminately benefited at the expense of creditors. To pay the public debt in a depreciated currency, whether it can be done legally or not, is to weaken if not destroy public faith. If they

had a rational conception of what national credit is, this consideration alone would give the agitators pause. When nearly two hundred years ago England was struggling to restore order to her finances, William III. pressed upon the House of Commons the importance of taking care of the public credit, and assured them that it could only be preserved by keeping sacred the maxim that "they shall never be losers who trust to a parliamentary security." Our national credit has rapidly advanced to the very first rank, and with upright dealing can easily be maintained there. It would not be necessary to perfect a great deal of the kind of legislation that is now being urged to put it on a level with the credit of Spain, or the defaulting states of South America.

There is a prevailing misconception as to where the gains and losses arising from the proposed change will fall.

A depreciated coinage will diminish the revenue of the Government by a far greater amount than will be saved in the payment of the bonds, so that the burden of taxes cannot be lightened in that way. It will cripple all institutions of learning and of charity that are maintained by endowments; it will tithe the assets of all the savings-banks and life-insurance companies; it will curtail the trust funds of widows and orphans, no matter in what form they may be held; it will defraud the frugal and prudent wholesale, for the benefit of the improvident and reckless. Relatively, the loss will fall heaviest on those who are too poor to get in debt, who work for wages or a salary. Those of the bond-holders to whom the now familiar term of "money-sharks" will in any degree apply will be found quite competent to take care of themselves. They live in the money-centres of the world; their finger is on the arteries of commerce, and they can watch the pulsations and guard against the perturbations; in the unsettled condition of things which would attend such a change, they will be best able, because in the best position, to hedge against their losses. Prices will, of course, adjust themselves to the new standard, but the adjustment will not be so sharp and rapid or exact as to cause the loss to fall just where it is intended it shall fall. The "sharks," we may be sure, will get from under, and the brunt of the suffering will strike just where it does in most cases—upon the poor, the ill-informed, the unready.

Of the ability of this nation to pay its debts in full, there is not the slightest question, and it is essentially dishonest for a debtor to compound at 90 cents when he can pay 100; but, if it be determined that it is necessary and right for the Government and other debtors to make such a composition—if it can be shown that it is a step dictated by a sincere desire to execute fair and impartial justice—we shall still be as much entitled as ever to object to its being done by reducing the standard of money. It is an attempt to accomplish by mean and paltry subterfuge that which, if done at all, should be done in a manly

way. If debts are to be scaled, let it be done openly, and the dividends, whatever they may be, paid in money at par.

A proposition to restore the old dollar, and make it a legal tender for everything except the interest and principal of the public debt and for customs duties, is said to find considerable favor. It is hard to understand how, after our prolonged experience of the derangement caused by having two unequal kinds of currency, such a scheme should be advocated. With one currency fit for paying bonds, customs duties, and foreign payments, and another not so fit, and therefore, of course, at a discount, we have a condition of affairs that is profitable to "money-sharks" and brokers alone. Every dollar which is paid as brokerage, growing out of the use of two kinds of currency, is a tax levied upon the people. If the sums which have been annually paid by consumers in the way of brokers' commissions since 1862, as a result of the depreciation of our currency, could be stated, and it could be shown by whom this tax has ultimately been paid, it would raise a party in favor of a single standard that would sweep everything before it. The tax has been levied indirectly, and paid unknowingly, but this has not lessened the burden of it—economic laws are none the less inexorable when their workings are obscure. And now, when we have almost emerged from under this load, it is proposed to put us back under it, not temporarily, but permanently, without even a distant hope of release.

There is one other proposition in regard to the reissue of silver: it is, to coin a silver dollar which shall contain enough metal to make it the equal of the present gold dollar. To this there is no moral objection, but there are grave economic ones. The rapid and violent fluctuations of the silver-market during the last two years show that forces are at work which are unusual in their nature and not yet understood, and the appeal can well be made to all prudent men whether it would not be better to wait a little before reintroducing into our currency so unstable an element. When the disturbing forces have expended themselves, and the silver-market has settled down to a normal condition, so that we may know what the price of silver really is in relation to other commodities, it will then be time enough to try to establish some fixed ratio between it and gold, and admit it as a legal tender.

But obvious as the lessons of history are, and pitilessly as the fallacies of those who think to make 90 equal 100 have been criticised, both by the pens of economists and the workings of natural laws, there is too much ground to fear that no reliance can be placed on the clearness or rectitude of popular convictions, and that we shall be called upon to vindicate once more the principles of monetary economy in the most painful and expensive way. There does not seem to be among our leaders either knowledge or virtue enough to protect us. A minority of the press and the business-men of the

larger towns of the country are alone opposing this scheme compounded of fraud and folly, and it is to be feared that their political influence is quite inadequate to stand against the urgency of the great majorities of the West and South.

SPONTANEOUS GENERATION.

By Prof. JOHN TYNDALL, F. R. S.

II.

LET us now return to London and fix our attention on the dust of *its* air. Suppose a room in which the house-maid has finished her work to be completely closed, with the exception of an aperture in a shutter through which a sunbeam enters and crosses the room. The floating dust reveals the track of the light. Let a lens be placed in the aperture to condense the beam. Its parallel rays are now converged to a cone, at the apex of which the dust is raised to almost unbroken whiteness by the intensity of its illumination. Defended from all glare, the eye is peculiarly sensitive to this scattered light. The floating dust of London rooms is organic, and may be burned without leaving visible residue. The action of a spirit-lamp flame upon the floating matter has been elsewhere thus described:

"In a cylindrical beam which strongly illuminated the dust of our laboratory, I placed an ignited spirit-lamp. Mingling with the flame, and round its rim, were seen curious wreaths of darkness resembling an intensely black smoke. On placing the flame at some distance below the beam, the same dark masses stormed upward. They were blacker than the blackest smoke ever seen issuing from the funnel of a steamer; and their resemblance to smoke was so perfect as to prompt the conclusion that the apparently pure flame of the alcohol-lamp required but a beam of sufficient intensity to reveal its clouds of liberated carbon.

"But is the blackness smoke? This question presented itself in a moment, and was thus answered: A red-hot poker was placed underneath the beam; from it the black wreaths also ascended. A large hydrogen-flame, which emits no smoke, was next employed, and it also produced with augmented copiousness those whirling masses of darkness. Smoke being out of the question, what is the darkness? It is simply that of stellar space; that is to say, blackness resulting from the absence from the track of the beam of all matter competent to scatter its light. When the flame was placed below the beam, the floating matter was destroyed *in situ;* and the heated air, freed from this matter, rose into the beam, jostled aside the illuminated particles, and substituted for their light the darkness due to its own perfect transparency. Nothing could more forcibly illustrate the invisibility of the agent which renders all things visible. The beam crossed, unseen, the black chasm formed by the transparent air, while, at both sides of the gap, the thick-strewed particles shone out like a luminous solid under the powerful illumination."[1]

[1] "Fragments of Science," fifth edition, pp. 128, 129.

Supposing an infusion intrinsically barren, but readily susceptible of putrefaction when exposed to common air, to be brought into contact with this unilluminable air, what would be the result? It would never putrefy. It might, however, be urged that the air is spoiled by its violent calcination. Oxygen passed through a spirit-lamp flame is, it may be thought, no longer the oxygen suitable for the development and maintenance of life. We have an easy escape from this difficulty, which is based, however, upon the unproved assumption that the air has been affected by the flame. Let a condensed beam be sent through a large flask or bolt-head containing common air. The track of the beam is seen within the flask—the dust revealing the light, and the light revealing the dust. Cork the flask, stuff its neck with cotton-wool, or simply turn it mouth downward and leave it undisturbed for a day or two. Examined afterward with the luminous beam, no track is visible; the light passes through the flask as through a vacuum. The floating matter has abolished itself, being now attached to the interior surface of the flask. Were it our object, as it will be subsequently, to effectually detain the dirt, we might coat that surface with some sticky substance. Here, then, without "torturing" the air in any way, we have found a means of ridding it, or rather of enabling it to rid itself, of floating matter.

We have now to devise a means of testing the action of such spontaneously purified air upon putrescible infusions. Wooden chambers, or cases, are accordingly constructed having glass fronts, side-windows, and back-doors. Through the bottoms of the chambers test-tubes pass air-tight, their open ends, for about one-fifth of the length of the tubes, being within the chambers. Provision is made for a free connection through sinuous channels between the inner and the outer air. Through such channels, though open, no dust will reach the chamber. The top of each chamber is perforated by a circular hole two inches in diameter and closed air-tight by a sheet of India-rubber. This is pierced in the middle by a pin, and through the pin-hole is pushed the shank of a long pipette, ending above in a small funnel. The shank also passes through a stuffing-box of cotton-wool moistened with glycerine; so that, tightly clasped by the rubber and wool, the pipette is not likely in its motions up and down to carry any dust into the chamber. The annexed woodcut shows a chamber with six test-tubes, its side-windows *w w*, its pipette *p C*, and its sinuous channels *a b* which connect the air of the chamber with the outer air.

The chamber is carefully closed and permitted to remain quiet for two or three days. Examined at the beginning by a beam sent through its windows, the air is found laden with floating matter, which in three days has wholly disappeared. To prevent its ever rising again into the chambers, the internal surface is coated with glycerine. The fresh but putrescible liquid is introduced into the six tubes in succession by means of the pipette. Permitted to remain

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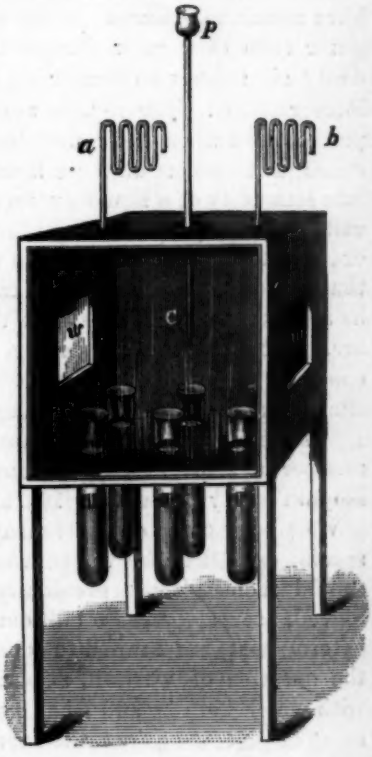
without further precaution, every one of the tubes would putrefy and fill itself with life. The liquid has been in contact with dust-laden air by which it has been infected, and the infection must be destroyed. This is done by plunging the six tubes into a bath of heated oil and boiling the infusion. The time requisite to destroy the infection depends wholly upon its nature. Two minutes' boiling suffices to destroy some contagia, whereas two hundred minutes' boiling fails to destroy others. After the infusion has been sterilized, the oil-bath is withdrawn, and the liquid, whose putrescibility has been in no way affected by the boiling, is abandoned to the air of the chamber.



With such chambers I tested, in the autumn and winter of 1875–'76, infusions of the most various kinds, embracing natural animal liquids, the flesh and viscera of domestic animals, game, fish, and vegetables. More than fifty moteless chambers, each with its series of infusions, were then tested, many of them repeatedly. There was no shade of uncertainty in any of the results. In every instance we had, within the chamber, perfect limpidity and sweetness, which in some cases lasted for more than a year—without the chamber, with the same infusion, putridity, and its characteristic smells. In no instance was the least countenance lent to the notion that an infusion deprived by heat of its inherent life, and placed in contact with air cleansed of its visibly suspended matter, has any power whatever to generate life anew.

Remembering, then, the number and variety of the infusions employed, and the strictness of our adherence to the rules of preparation laid down by the heterogenists themselves; remembering that we have operated upon the very substances recommended by them as capable of furnishing even in untrained hands easy and decisive proofs of spontaneous generation, and that we have added to their substances many others of our own—if this pretended generative power were a reality, surely it must have manifested itself somewhere. Speaking roundly, I should say that at least 500 chances have been given to it, but it has nowhere appeared. The argument is now to be closed and

clinched by an experiment which will remove every residue of doubt as to the ability of the infusions to sustain life. We open the back-doors of our sealed chambers, and permit the common air with its floating particles to have access to our tubes. For three months they have remained pellucid and sweet—flesh, fish, and vegetable extracts, purer than ever cook manufactured. Three days' exposure to the dusty air suffices to render them muddy, fetid, and swarming with infusorial life. The liquids are thus proved, one and all, ready for putrefaction when the contaminating agent is applied. I invite my colleague to reflect on these facts. How will he account for the absolute immunity of a liquid exposed for months in a warm room to optically pure air, and its infallible putrefaction in a few days when exposed to dust-laden air? He must, I submit, bow to the conclusion that the dust-particles are the cause of putrefactive life. And, unless he accepts the hypothesis that these particles, being dead in the air, are, in the liquid, miraculously kindled into living things, he must conclude that the life we have observed springs from germs or organisms diffused through the atmosphere.

The experiments with hermetically-sealed flasks have reached the number of 940. A sample group of 130 of them were laid before the Royal Society on January 13, 1876. They were utterly free from life, having been completely sterilized by three minutes' boiling. I took special care that the temperatures to which the flasks were exposed should include those previously alleged to be efficient. I copied, indeed, accurately the conditions laid down by our most conspicuous heterogenist, but I failed to corroborate him. He then laid stress on the question of warmth, suddenly adding 30° to the temperatures with which both he and I had previously worked. Waiving all argument or protest against the caprice thus manifested, I met this new requirement also. The sealed tubes, which had proved barren in the Royal Institution, were suspended in perforated boxes, and placed under the supervision of an intelligent assistant in the Turkish Bath in Jermyn Street. From two to six days had been allowed for the generation of organisms in hermetically-sealed tubes. Mine remained in the washing-room of the bath for nine days. Thermometers placed in the boxes, and read off twice or three times a day, showed the temperature to vary from a minimum of 101° to a maximum of 112° Fahr. At the end of nine days the infusions were as clear as at the beginning. They were then removed to a warmer position. A temperature of 115° had been mentioned as particularly favorable to spontaneous generation. For fourteen days the temperature of the Turkish bath hovered about this point, falling once as low as 106°, reaching 116° on three occasions, 118° on one, and 119° on two. The result was quite the same as that just recorded. The higher temperatures proved perfectly incompetent to develop life.

Taking the actual experiment we have made as a basis of calcula-

tion, if our 940 flasks were opened on the hay-loft of the Bel Alp 858 of them would become filled with organisms. The escape of the remaining 82 strengthens our case against the heterogenists, proving as it does conclusively that not in the air, nor in the infusions, nor in anything continuous diffused through the air, but in *discrete particles* nourished by the infusions, we are to seek the cause of life. Our experiment proves these particles to be in some cases so far apart on the hay-loft as to permit 10 per cent. of our flasks to take in air without contracting contamination. A quarter of a century ago Pasteur proved the cause of "so-called spontaneous generation" to be *discontinuous*. I have already referred to his observation that 12 out of 20 flasks opened on the plains escaped infection, while 19 out of 20 flasks opened on the Mer de Glace escaped. Our own experiment at the Bel Alp is a more emphatic instance of the same kind, 90 per cent. of the flasks opened in the hay-loft being smitten, while not one of those opened on the free mountain-ledge was attacked. The power of the air as regards putrefactive infection is incessantly changing through natural causes, and we are able to alter it at will. Of a number of flasks opened in 1876 in the laboratory of the Royal Institution, 42 per cent. were smitten, while 58 per cent. escaped. In 1877 the proportion in the same laboratory was 68 per cent. smitten to 32 intact. The greater mortality, so to speak, of the infusions in 1877 was due to the presence of hay which diffused its germinal dust in the laboratory air, causing it to approximate, as regards infective virulence, to the air of the Alpine loft. I would ask my friend to bring his scientific penetration to bear upon all the foregoing facts. They do not prove spontaneous generation to be "impossible." My assertions, however, relate not to "possibilities," but to *proofs*, and the experiments just described do most distinctly prove the evidence on which the heterogenist relies to be written on waste paper.

My friend will not, I am persuaded, dispute these results; but he may be disposed to urge that other able and honorable men working at the same subject have arrived at conclusions different from mine. Most freely granted, but let me here recur to the remarks already made in speaking of the experiments of Spallanzani, to the effect that the failure of others to confirm his results by no means upsets their evidence. To fix the ideas, let us suppose that my colleague comes to the laboratory of the Royal Institution, repeats there my experiments, and obtains confirmatory results; and that he then goes to University or King's College, where, operating with the same infusions, he obtains contradictory results. Will he be disposed to conclude that the self-same substance is barren in Albemarle Street and fruitful in Gower Street or the Strand? His Alpine experience has already made known to him the literally infinite differences existing between different samples of air as regards their capacity for putrefactive infection. And, possessing this knowledge, will he not

substitute, for the adventurous conclusion that an organic infusion is barren at one place and spontaneously generative at another, the more rational and obvious one that the air of the two localities which has had access to the infusion is infective in different degrees?

As regards workmanship, moreover, he will not fail to bear in mind that *fruitfulness* may be due to errors of manipulation, while *barrenness* involves the presumption of correct experiment. It is only the careful worker that can secure the latter, while it is open to every novice to obtain the former. Barrenness is the result at which the conscientious experimenter, whatever his theoretic convictions may be, ought to aim, omitting no pains to secure it, and resorting, only when there is no escape from it, to the conclusion that the life observed comes from no source which correct experiment could neutralize or avoid. Let us again take a definite case. Supposing my colleague to operate with the same apparent care on 100 infusions—or rather on 100 samples of the same infusion—and that 50 of them prove fruitful and 50 barren. Are we to say that the evidence for and against heterogeny is equally balanced? There are some who would not only say this, but who would treasure up the 50 fruitful flasks, as "positive results, and lower the evidential value of the 50 barren flasks by labeling them "negative" results. This, as shown by Dr. William Roberts, is an exact inversion of the true order of the terms positive and negative.[1] Not such, I trust, would be the course pursued by my friend. As regards the 50 fruitful flasks he would, I doubt not, repeat the experiment with redoubled care and scrutiny, and, not by one repetition only, but by many, assure himself that he had not fallen into error. Such faithful scrutiny fully carried out would infallibly lead him to the conclusion that here, as in all other cases, the evidence in favor of spontaneous generation crumbles in the grasp of the competent inquirer.

The botanist knows that different seeds possess different powers of resistance to heat.[2] Some are killed by a momentary exposure to the boiling temperature, while others withstand it for several hours. Most of our ordinary seeds are rapidly killed, while Pouchet made known to the Paris Academy of Sciences, in 1866, that certain seeds, which had been transported in fleeces of wool from Brazil, germinated after four hours' boiling. The germs of the air vary as much among themselves as the seeds of the botanist. In some localities the diffused germs are so tender that boiling for five minutes, or even less, would be sure to destroy them all; in other localities the diffused germs are

[1] *See* his truly philosophical remarks on this head in the *British Medical Journal*, 1876, p. 282.

[2] I am indebted to Dr. Thistleton Dyer for various illustrations of such differences. It is, however, surprising that a subject of such high scientific importance should not have been more thoroughly explored. Here the scoundrels who deal in killed seeds might be able to add to our knowledge.

so obstinate that many hours' boiling would be requisite to deprive them of their power of germination. The absence or presence of a truss of desiccated hay would produce differences as great as those here described. The greatest endurance that I have ever observed—and I believe it is the greatest on record—was a case of survival after eight hours' boiling. As regards their power of resisting heat, the infusorial germs of our atmosphere might be classified under the following and intermediate heads: Killed in five minutes; not killed in five minutes but killed in fifteen; not killed in fifteen minutes but killed in thirty; not killed in thirty minutes but killed in an hour; not killed in an hour but killed in two hours; not killed in two but killed three hours; not killed in three but killed in four hours. I have had several cases of survival after four and five hours' boiling, some survivals after six, and one after eight hours' boiling. Thus far has experiment actually reached, but there is no valid warrant for fixing upon even eight hours as the extreme limit of vital resistance. Probably more extended researches (though mine have been very extensive) would reveal germs more obstinate still. It is also certain that we might begin earlier, and find germs which are destroyed by a temperature far below that of boiling water. In the presence of such facts, to speak of *a* death-point of bacteria and their germs would be mere nonsense—but of this more anon.

We have now to test one of the principal foundations of the doctrine of spontaneous generation as formulated in this country. With this view, I place before my friend and co-inquirer two liquids which have been kept for six months in one of our sealed chambers, exposed to optically pure air. The one is a mineral solution containing in proper proportions all the substances which enter into the composition of bacteria, the other is an infusion of turnip—it might be any one of a hundred other infusions, animal or vegetable. Both liquids are as clear as distilled water, and there is no trace of life in either of them. They are, in fact, completely sterilized. A mutton-chop, over which a little water has been poured to keep its juices from drying up, has lain for three days upon a plate in our warm room. It smells offensively. Placing a drop of the fetid mutton-juice under a microscope, it is found swarming with the bacteria which live by putrefaction, and without which no putrefaction can occur. With a speck of the swarming liquid I inoculate the clear mineral solution and the clear turnip-infusion, as a surgeon might inoculate an infant with vaccine lymph. In four-and-twenty hours the transparent liquids have become turbid throughout, and, instead of being barren as at first, they are teeming with life. The experiment may be repeated a thousand times with the same invariable result. To the naked eye the liquids at the beginning were alike, being both equally transparent—to the naked eye they are alike at the end, being both equally muddy. Instead of putrid mutton-juice we might take as a source of infection

any one of a hundred other putrid liquids, animal or vegetable. So long as the liquid contains the living bacteria, a speck of it communicated to the clear mineral solution, or to the clear turnip-infusion, produces in twenty-four hours the effect that we have described.

We now vary the experiment thus: Opening the back-door of another closed chamber which has contained for months the pure mineral solution and the pure turnip-infusion side by side, I drop into each of them a small pinch of laboratory dust. The effect here is tardier than when the speck of putrid liquid was employed. In three days, however, after its infection with the dust, the turnip-infusion is muddy, and swarming as before with bacteria. But what about the mineral solution which, in our first experiment, behaved in a manner undistinguishable from the turnip-juice? At the end of three days there is not a bacterium to be found in it. At the end of three weeks it is equally innocent of bacterial life. We may repeat the experiment with the solution and the infusion a hundred times, with the same invariable result. Always in the case of the latter the sowing of the atmospheric dust yields a crop of bacteria—never in the former does the dry germinal matter kindle into active life.[1] What is the inference which the reflecting mind must draw from this experiment? Is it not as clear as day that while both liquids are able to feed the bacteria and to enable them to increase and multiply, *after they have been once fully developed*, only one of the liquids is able to develop into active bacteria the germinal dust of the air?

I invite my friend to reflect upon this conclusion; he will, I think, see that there is no escape from it. He may, if he prefers it, hold the opinion, which I consider erroneous, that bacteria exist in the air, not as germs but as desiccated organisms. The inference remains that, while the one liquid is able to force the passage from the inactive to the active state, the other is not.

But this is not at all the inference which has been drawn from experiments with the mineral solution. Seeing its ability to nourish bacteria when once inoculated with the living active organism, and observing that no bacteria appeared in the solution after long exposure to the air, the inference was drawn that *neither bacteria nor their germs existed in the air.* Throughout Germany the ablest literature of the subject, even that opposed to heterogeny, is infected with this error; while heterogenists at home and abroad have based upon it a triumphant demonstration of their doctrine. It is proved, they say, by the deportment of the mineral solution that neither bacteria nor their germs exist in the air; hence, if, on exposing a thoroughly sterilized turnip-infusion to the air, bacteria appear, they must of necessity have been spontaneously generated. In the words

[1] This is the deportment of the mineral solution as described by others. My own experiments would lead me to say that the development of the bacteria, though exceedingly slow and difficult, is not impossible.

of Dr. Bastian, uttered not in a popular book, but in the "Proceedings of the Royal Society,"[1] with reference to this very experiment: "We can only infer that while the boiled saline solution is quite incapable of engendering bacteria, such organisms are able to arise *de novo* in the boiled organic infusion." I would ask my eminent colleague what he thinks of this reasoning now? The *datum* is, "A mineral solution exposed to common air does not develop bacteria:" the *inference* is, "Therefore, if a turnip-infusion similarly exposed develop bacteria, they must be spontaneously generated." The inference, on the face of it, is an unwarranted one. But, while as matter of logic it is inconclusive, as matter of fact it is chimerical. London air is as surely charged with the germs of bacteria as London chimneys are with smoke. The inference just referred to is completely disposed of by the simple question: "Why, when your sterilized organic infusion is exposed to optically pure air, should this generation of life *de novo* utterly cease? Why should I be able to preserve my turnip-juice side by side with your saline solution for the three hundred and sixty-five days of the year, in free connection with the general atmosphere, on the sole condition that the portion of that atmosphere in contact with the juice shall be visibly free from floating dust, while three days' exposure to that dust fills it with bacteria?" Am I over-sanguine in hoping that, as regards the argument here set forth, he who runs may read, and he who reads may understand? Let me add, however, that while exposing the fallacy of the inferences drawn from it, I regard the observation that the boiled saline solution can sustain the developed organisms, while it cannot develop them from the dry germinal matter of the air, as an important addition to our knowledge. We are indebted for it to Dr. Burdon-Sanderson, who soon saw that his first interpretation of it went too far, and who, in a communication recently presented to the Royal Society, abandons the interpretation altogether.

We now proceed to the calm and thorough consideration of another subject, more important if possible than the foregoing one, but like it somewhat difficult to seize by reason of the very opulence of the phraseology, logical and rhetorical, in which it has been set forth. The subject now to be considered relates to what has been called "the death-point of bacteria." Those who happen to be acquainted with the modern English literature of the question will remember how challenge after challenge has been issued to panspermatists in general, and to one or two home workers in particular, to come to close quarters on this cardinal point. It is obviously the stronghold of the English heterogenist. "Water," he says, "is boiling merrily over a fire, when some luckless person upsets the vessel so that the heated fluid exercises its scathing influence upon an uncovered portion of the body—hand, arm, or face. Here at all events there is no room for

[1] Vol. xxi., p. 130.

doubt. Boiling water unquestionably exercises a most pernicious and rapidly-destructive effect upon the living matter of which we are composed."[1] And, lest it should be supposed that it is the high organization which, in this case, renders the body susceptible to heat, he refers to the action of boiling water on the hen's-egg to dissipate the notion. "The conclusion," he says, "would seem to force itself upon us that there is something intrinsically deleterious in the action of boiling water upon living matter—whether this matter be of high or of low organization."[2] Again, at another place, "It has been shown that the briefest exposure to the influence of boiling water is destructive of all living matter."[3] Throughout his prolonged disquisitions on this subject, Dr. Bastian makes special kinds of living matter do duty for *all* kinds. To invalidate the foregoing statements it is only necessary to say that eight years before they were made it had been known to the wool-staplers of Elbœuf, and Pouchet had published the fact in the *Comptes-Rendus of the Paris Academy of Sciences*,[4] that the desiccated seeds of the Brazilian plant *medicago* survived fully four hours' boiling. Pouchet himself boiled the seeds, and found some of them swollen and disintegrated, while others remained hard and unswollen. Sown in the same earth, the latter germinated while the former did not. So much for the heterogenist's mistake regarding ordinary seeds; we must now examine whether no error underlies his experiments and his reasonings as to "the death-point of bacteria."

The experiments already recorded plainly show that there is a marked difference between the dry bacterial matter of the air, and the wet, soft, and active bacteria of putrefying organic liquids. The one can be luxuriantly bred in the saline solution, the others refuse to be born there, while both of them are copiously developed in a sterilized turnip-infusion. Inferences, as we have already seen, founded on the deportment of the one liquid cannot with the warrant of scientific logic be extended to the other. But this is exactly what the heterogenist has done, thus repeating, as regards the death-point of bacteria, the error into which he fell concerning the germs of the air. Let us boil our muddy mineral solution with its swarming bacteria for five minutes. In the soft, succulent condition in which they exist in the solution not one of them escapes destruction. The same is true of the turnip-infusion if it be inoculated with the living bacteria only—the aërial dust being carefully excluded. In both cases the dead organisms sink to the bottom of the liquid, and without reinoculation no fresh organisms will arise. But the case is entirely different when we inoculate our turnip-infusion with the desiccated germinal matter afloat in the air.

The "death-point" of bacteria is the maximum temperature at

[1] Bastian, "Evolution," p. 133. [2] Ibid., p. 135. [3] Ibid., p. 46.
[4] Vol. lxiii., p. 939.

which they can live, or the minimum temperature at which they cease to live. If, for example, they survive a temperature of 140°, and do not survive a temperature of 150°, the death-point lies somewhere between these two temperatures. Vaccine lymph, for example, is proved by Messrs. Braidwood and Vacher to be deprived of its power of infection by brief exposure to a temperature between 140° and 150° Fahr. This may be regarded as the death-point of the lymph, or rather of the particles diffused in the lymph, which constitute the real contagium. If no time, however, be named for the application of the heat, the term "death-point" is a vague one. An infusion, for example, which will resist five hours' continuous exposure to the boiling temperature, will succumb to five days' exposure to a temperature 50° below that of boiling. The fully-developed, soft bacteria of putrefying liquids are not only killed by five minutes' boiling, but by less than a single minute's boiling—indeed, they are slain at about the same temperature as the vaccine. The same is true of the plastic, active bacteria of the turnip-infusion.[1] But, instead of choosing a putrefying liquid for inoculation, let us prepare and employ our inoculating substance in the following simple way: Let a small wisp of hay, desiccated by age, be washed in a glass of water, and let a perfectly sterilized turnip-infusion be inoculated with the washing liquid. After three hours' continuous boiling the infusion thus infected will often develop luxuriant bacterial life. Precisely the same occurs if a turnip-infusion be prepared in an atmosphere well charged with desiccated hay-germs. The infusion in this case infects itself without special inoculation, and its subsequent resistance to sterilization is often very great. On the 1st of March last I purposely infected the air of our laboratory with the germinal dust of a sapless kind of hay mown in 1875. Ten groups of flasks were charged with turnip infusion prepared in the infected laboratory, and were afterward subjected to the boiling temperature for periods varying from 15 minutes to 240 minutes. Out of the ten groups only one was sterilized—that, namely, which had been boiled for four hours. Every flask of the nine groups which had been boiled for 15, 30, 45, 60, 75, 90, 105, 120, and 180 minutes respectively, bred organisms afterward. The same is true of other vegetable infusions. On the 28th of February last, for example, I boiled six flasks, containing cucumber-infusion prepared in an infected atmosphere, for periods of 15, 30, 45, 60, 120, and 180 minutes. Every flask of the group subsequently developed organisms. On the same day, in the case of three flasks, the boiling was prolonged to 240, 300, and 360 minutes; and these three flasks were completely

[1] In my paper in the "Philosophical Transactions" for 1876, I pointed out and illustrated experimentally the difference, as regards rapidity of development, between water-germs and air-germs; the growth from the already softened water-germs proving to be practically as rapid as from developed bacteria. This preparedness of the germ for rapid development is associated with its preparedness for rapid destruction.

sterilized. Animal infusions, which under ordinary circumstances are rendered infallibly barren by five minutes' boiling, behave like the vegetable infusions in an infective atmosphere. On the 30th of March, for example, five flasks were charged with a clear infusion of beef and boiled for 60 minutes, 120 minutes, 180 minutes, 240 minutes, and 300 minutes respectively. Every one of them became subsequently crowded with organisms, and the same happened to a perfectly pellucid mutton-infusion prepared at the same time. The cases are to be numbered by hundreds in which similar powers of resistance were manifested by infusions of the most diverse kinds.

In the presence of such facts I would ask my eminent colleague whether it is necessary to dwell for a single instant on the one-sidedness of the evidence which led to the conclusion that all living matter has its life destroyed by "the briefest exposure to the influence of boiling water." An infusion proved to be barren by six months' exposure to moteless air kept at a temperature of 90° Fahr., when inoculated with full-grown, active bacteria, fills itself in two days with organisms so sensitive as to be killed by a few minutes' exposure to a temperature much below that of boiling water. But the extension of this result to the desiccated germinal matter of the air is without warrant or justification. This is obvious without going beyond the argument itself. But we have gone far beyond the argument and proved by multiplied experiment the alleged destruction of all living matter by the briefest exposure to the influence of boiling water to be a delusion. The whole logical edifice raised upon this basis falls, therefore, to the ground; and the argument that bacteria and their germs being destroyed at 140° must, if they appear after exposure to 212°, be spontaneously generated, is, I trust, silenced forever.

Through the precautions, variations, and repetitions observed and executed with the view of rendering its results secure, the separate vessels employed in this inquiry have mounted up in two years to nearly 10,000. Here, however, and with good reason, the editor cries, "Halt!" I had hoped, when I began, to carry the argument further. Besides the philosophic interest attaching to the problem of life's origin, which will be always immense, there are the practical interests involved in the application of the doctrines here discussed to surgery and medicine. The antiseptic system, at which I have already glanced, illustrates the manner in which beneficent results of the gravest moment follow in the wake of clear theoretic insight. Surgery was once a noble art; it is now, as well, a noble science. Prior to the introduction of the antiseptic system, the thoughtful surgeon could not have failed to learn empirically that there is something in the air which often defeated the most consummate operative skill. That something the antiseptic treatment destroys or renders innocuous. At King's College Mr. Lister operates and dresses while a fine shower of mixed carbolic acid and water, produced in the simplest manner,

falls upon the wound, the lint and gauze employed in the subsequent dressing being duly saturated with the antiseptic. At St. Bartholomew's Mr. Callender employs the dilute carbolic acid without the spray; but, as regards the real point aimed at—the preventing of the wound from becoming a nidus for the propagation of septic bacteria—the practice in both hospitals is the same. Commending itself as it does to the scientifically-trained mind, the antiseptic system has struck deep root in Germany.

It would also have given me pleasure to point out the present position of the "germ-theory" in reference to the phenomena of infectious disease, distinguishing arguments based on analogy—which, however, are terribly strong—from those based on actual observation. I should have liked to follow up the account I have already given[1] of the truly excellent researches of a young and an unknown German physician named Koch, on splenic fever, by an account of what Pasteur has recently done with reference to the same subject. Here we have before us a living contagium of the most fatal power, which we can follow from the beginning to the end of its life-cycle.[2] We find it in the blood or spleen of a smitten animal in the state say of short motionless rods. We place these rods in a nutritive liquid on the warm stage of the microscope, and see them lengthening into filaments which lie side by side, or, crossing each other, become coiled into knots of a complexity not to be unraveled. We finally see those filaments resolving themselves into innumerable spores, each with death potentially housed within it, yet not to be distinguished microscopically from the harmless germs of *Bacillus subtilis*. The bacterium of splenic fever is called *Bacillus anthracis*. This formidable organism was shown to me by M. Pasteur in Paris last July. His recent investigations regarding the part it plays pathologically certainly rank among the most remarkable labors of that remarkable man. Observer after observer had strayed and fallen in this land of pitfalls, a multitude of opposing conclusions and mutually-destructive theories being the result. In association with his younger physiological colleague M. Joubert, Pasteur struck in amid the chaos, and soon reduced the whole of it to harmony. They proved, among other things, that in cases where previous observers in France had supposed themselves to be dealing solely with splenic fever, another equally virulent factor was simultaneously active. Splenic fever was often overmastered by septicæmia, and results due solely to the latter had been frequently made the ground of pathological inferences regarding the character and cause of the former. Combining duly the two factors, all the previous irregularities disappeared, every result obtained receiving the fullest explanation. On studying the account

[1] *Fortnightly Review*, November, 1876.

[2] Dallinger and Drysdale had previously shown what skill and patience can accomplish by their admirable observations on the life-history of the monads.

of this masterly investigation, the words wherewith Pasteur himself feelingly alludes to the difficulties and dangers of the experimenter's art came home to me with especial force: "J'ai tant de fois éprouvé que dans cet art difficile de l'expérimentation les plus habiles bronchent à chaque pas, et que l'interprétation des faits n'est pas moins périlleuse."[1]

ILLUSTRATIONS OF THE LOGIC OF SCIENCE.

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THIRD PAPER.—THE DOCTRINE OF CHANCES.

I.

IT is a common observation that a science first begins to be exact when it is quantitatively treated. What are called the exact sciences are no others than the mathematical ones. Chemists reasoned vaguely until Lavoisier showed them how to apply the balance to the verification of their theories, when chemistry leaped suddenly into the position of the most perfect of the classificatory sciences. It has thus become so precise and certain that we usually think of it along with optics, thermotics, and electrics. But these are studies of general laws, while chemistry considers merely the relations and classification of certain objects; and belongs, in reality, in the same category as systematic botany and zoölogy. Compare it with these last, however, and the advantage that it derives from its quantitative treatment is very evident.

The rudest numerical scales, such as that by which the mineralogists distinguish the different degrees of hardness, are found useful. The mere counting of pistils and stamens sufficed to bring botany out of total chaos into some kind of form. It is not, however, so much from *counting* as from *measuring*, not so much from the conception of number as from that of continuous quantity, that the advantage of mathematical treatment comes. Number, after all, only serves to pin us down to a precision in our thoughts which, however beneficial, can seldom lead to lofty conceptions, and frequently descends to pettiness. Of those two faculties of which Bacon speaks, that which marks differences and that which notes resemblances, the employment of number can only aid the lesser one; and the excessive use of it must tend to narrow the powers of the mind. But the conception of continuous quantity has a great office to fulfill, independently of any attempt at precision. Far from tending to the exaggeration of differences, it is the direct instrument of the finest generalizations. When

[1] *Comptes Rendus*, lxxxiii., p. 177.

a naturalist wishes to study a species, he collects a considerable number of specimens more or less similar. In contemplating them, he observes certain ones which are more or less alike in some particular respect. They all have, for instance, a certain S-shaped marking. He observes that they are not *precisely* alike, in this respect; the S has not precisely the same shape, but the differences are such as to lead him to believe that forms could be found intermediate between any two of those he possesses. He, now, finds other forms apparently quite dissimilar—say a marking in the form of a C—and the question is, whether he can find intermediate ones which will connect these latter with the others. This he often succeeds in doing in cases where it would at first be thought impossible; whereas, he sometimes finds those which differ, at first glance, much less, to be separated in Nature by the non-occurrence of intermediaries. In this way, he builds up from the study of Nature a new general conception of the character in question. He obtains, for example, an idea of a leaf which includes every part of the flower, and an idea of a vertebra which includes the skull. I surely need not say much to show what a logical engine there is here. It is the essence of the method of the naturalist. How he applies it first to one character, and then to another, and finally obtains a notion of a species of animals, the differences between whose members, however great, are confined within limits, is a matter which does not here concern us. The whole method of classification must be considered later; but, at present, I only desire to point out that it is by taking advantage of the idea of continuity, or the passage from one form to another by insensible degrees, that the naturalist builds his conceptions. Now, the naturalists are the great builders of conceptions; there is no other branch of science where so much of this work is done as in theirs; and we must, in great measure, take them for our teachers in this important part of logic. And it will be found everywhere that the idea of continuity is a powerful aid to the formation of true and fruitful conceptions. By means of it, the greatest differences are broken down and resolved into differences of degree, and the incessant application of it is of the greatest value in broadening our conceptions. I propose to make a great use of this idea in the present series of papers; and the particular series of important fallacies, which, arising from a neglect of it, have desolated philosophy, must further on be closely studied. At present, I simply call the reader's attention to the utility of this conception.

In studies of numbers, the idea of continuity is so indispensable, that it is perpetually introduced even where there is no continuity in fact, as where we say that there are in the United States 10.7 inhabitants per square mile, or that in New York 14.72 persons live in the average house.[1] Another example is that law of the distribu-

[1] This mode of thought is so familiarly associated with all exact numerical consideration, that the phrase appropriate to it is imitated by shallow writers in order to produce

tion of errors which Quetelet, Galton, and others, have applied with so much success to the study of biological and social matters. This application of continuity to cases where it does not really exist illustrates, also, another point which will hereafter demand a separate study, namely, the great utility which fictions sometimes have in science.

II.

The theory of probabilities is simply the science of logic quantitatively treated. There are two conceivable certainties with reference to any hypothesis, the certainty of its truth and the certainty of its falsity. The numbers *one* and *zero* are appropriated, in this calculus, to marking these extremes of knowledge; while fractions having values intermediate between them indicate, as we may vaguely say, the degrees in which the evidence leans toward one or the other. The general problem of probabilities is, from a given state of facts, to determine the numerical probability of a possible fact. This is the same as to inquire how much the given facts are worth, considered as evidence to prove the possible fact. Thus the problem of probabilities is simply the general problem of logic.

Probability is a continuous quantity, so that great advantages may be expected from this mode of studying logic. Some writers have gone so far as to maintain that, by means of the calculus of chances, every solid inference may be represented by legitimate arithmetical operations upon the numbers given in the premises. If this be, indeed, true, the great problem of logic, how it is that the observation of one fact can give us knowledge of another independent fact, is reduced to a mere question of arithmetic. It seems proper to examine this pretension before undertaking any more recondite solution of the paradox.

But, unfortunately, writers on probabilities are not agreed in regard to this result. This branch of mathematics is the only one, I believe, in which good writers frequently get results entirely erroneous. In elementary geometry the reasoning is frequently fallacious, but erroneous conclusions are avoided; but it may be doubted if there is a single extensive treatise on probabilities in existence which does not contain solutions absolutely indefensible. This is partly owing to the want of any regular method of procedure; for the subject involves too many subtilties to make it easy to put its problems into equations without such an aid. But, beyond this, the fundamental principles of its calculus are more or less in dispute. In regard to that class of questions to which it is chiefly applied for practical purposes, there is comparatively little doubt; but in regard to others to which it has been sought to extend it, opinion is somewhat unsettled.

the appearance of exactitude where none exists. Certain newspapers which affect a learned tone talk of "the average man," when they simply mean *most men*, and have no idea of striking an average.

This last class of difficulties can only be entirely overcome by making the idea of probability perfectly clear in our minds in the way set forth in our last paper.

III.

To get a clear idea of what we mean by probability, we have to consider what real and sensible difference there is between one degree of probability and another.

The character of probability belongs primarily, without doubt, to certain inferences. Locke explains it as follows: After remarking that the mathematician positively knows that the sum of the three angles of a triangle is equal to two right angles because he apprehends the geometrical proof, he thus continues: "But another man who never took the pains to observe the demonstration, hearing a mathematician, a man of credit, affirm the three angles of a triangle to be equal to two right ones, *assents* to it; i. e., receives it for true. In which case the foundation of his assent is the probability of the thing, the proof being such as, for the most part, carries truth with it; the man on whose testimony he receives it not being wont to affirm anything contrary to, or besides his knowledge, especially in matters of this kind." The celebrated "Essay concerning Humane Understanding" contains many passages which, like this one, make the first steps in profound analyses which are not further developed. It was shown in the first of these papers that the validity of an inference does not depend on any tendency of the mind to accept it, however strong such tendency may be; but consists in the real fact that, when premises like those of the argument in question are true, conclusions related to them like that of this argument are also true. It was remarked that in a logical mind an argument is always conceived as a member of a *genus* of arguments all constructed in the same way, and such that, when their premises are real facts, their conclusions are so also. If the argument is demonstrative, then this is always so; if it is only probable, then it is for the most part so. As Locke says, the probable argument is "*such as* for the most part carries truth with it."

According to this, that real and sensible difference between one degree of probability and another, in which the meaning of the distinction lies, is that in the frequent employment of two different modes of inference, one will carry truth with it oftener than the other. It is evident that this is the only difference there is in the existing fact. Having certain premises, a man draws a certain conclusion, and as far as this inference alone is concerned the only possible practical question is whether that conclusion is true or not, and between existence and non-existence there is no middle term. "Being only is and nothing is altogether not," said Parmenides; and this is in strict accordance with the analysis of the conception of reality given in the last

paper. For we found that the distinction of reality and fiction depends on the supposition that sufficient investigation would cause one opinion to be universally received and all others to be rejected. That presupposition involved in the very conceptions of reality and figment involves a complete sundering of the two. It is the heaven-and-hell idea in the domain of thought. But, in the long run, there is a real fact which corresponds to the idea of probability, and it is that a given mode of inference sometimes proves successful and sometimes not, and that in a ratio ultimately fixed. As we go on drawing inference after inference of the given kind, during the first ten or hundred cases the ratio of successes may be expected to show considerable fluctuations; but when we come into the thousands and millions, these fluctuations become less and less; and if we continue long enough, the ratio will approximate toward a fixed limit. We may therefore define the probability of a mode of argument as the proportion of cases in which it carries truth with it.

The inference from the premise, A, to the conclusion, B, depends, as we have seen, on the guiding principle, that if a fact of the class A is true, a fact of the class B is true. The probability consists of the fraction whose numerator is the number of times in which both A and B are true, and whose denominator is the total number of times in which A is true, whether B is so or not. Instead of speaking of this as the probability of the inference, there is not the slighest objection to calling it the probability that, if A happens, B happens. But to speak of the probability of the event B, without naming the condition, really has no meaning at all. It is true that when it is perfectly obvious what condition is meant, the ellipsis may be permitted. But we should avoid contracting the habit of using language in this way (universal as the habit is), because it gives rise to a vague way of thinking, as if the action of causation might either determine an event to happen or determine it not to happen, or leave it more or less free to happen or not, so as to give rise to an *inherent* chance in regard to its occurrence. It is quite clear to me that some of the worst and most persistent errors in the use of the doctrine of chances have arisen from this vicious mode of expression.[1]

IV.

But there remains an important point to be cleared up. According to what has been said, the idea of probability essentially belongs to a kind of inference which is repeated indefinitely. An individual inference must be either true or false, and can show no effect of probability; and, therefore, in reference to a single case considered in

[1] The conception of probability here set forth is substantially that first developed by Mr. Venn, in his "Logic of Chance." Of course, a vague apprehension of the idea had always existed, but the problem was to make it perfectly clear, and to him belongs the credit of first doing this.

itself, probability can have no meaning. Yet if a man had to choose between drawing a card from a pack containing twenty-five red cards and a black one, or from a pack containing twenty-five black cards and a red one, and if the drawing of a red card were destined to transport him to eternal felicity, and that of a black one to consign him to everlasting woe, it would be folly to deny that he ought to prefer the pack containing the larger proportion of red cards, although, from the nature of the risk, it could not be repeated. It is not easy to reconcile this with our analysis of the conception of chance. But suppose he should choose the red pack, and should draw the wrong card, what consolation would he have? He might say that he had acted in accordance with reason, but that would only show that his reason was absolutely worthless. And if he should choose the right card, how could he regard it as anything but a happy accident? He could not say that if he had drawn from the other pack, he might have drawn the wrong one, because an hypothetical proposition such as, "if A, then B," means nothing with reference to a single case. Truth consists in the existence of a real fact corresponding to the true proposition. Corresponding to the proposition, "if A, then B," there may be the fact that *whenever* such an event as A happens such an event as B happens. But in the case supposed, which has no parallel as far as this man is concerned, there would be no real fact whose existence could give any truth to the statement that, if he had drawn from the other pack, he might have drawn a black card. Indeed, since the validity of an inference consists in the truth of the hypothetical proposition that *if* the premises be true the conclusion will also be true, and since the only real fact which can correspond to such a proposition is that whenever the antecedent is true the consequent is so also, it follows that there can be no sense in reasoning in an isolated case, at all.

These considerations appear, at first sight, to dispose of the difficulty mentioned. Yet the case of the other side is not yet exhausted. Although probability will probably manifest its effect in, say, a thousand risks, by a certain proportion between the numbers of successes and failures, yet this, as we have seen, is only to say that it certainly will, at length, do so. Now the number of risks, the number of probable inferences, which a man draws in his whole life, is a finite one, and he cannot be absolutely *certain* that the mean result will accord with the probabilities at all. Taking all his risks collectively, then, it cannot be certain that they will not fail, and his case does not differ, except in degree, from the one last supposed. It is an indubitable result of the theory of probabilities that every gambler, if he continues long enough, must ultimately be ruined. Suppose he tries the martingale, which some believe infallible, and which is, as I am informed, disallowed in the gambling-houses. In this method of playing, he first bets say $1; if he loses it he bets $2; if he loses that

he bets $4; if he loses that he bets $8; if he then gains he has lost $1+2+4=7$, and he has gained $1 more; and no matter how many bets he loses, the first one he gains will make him $1 richer than he was in the beginning. In that way, he will probably gain at first; but, at last, the time will come when the run of luck is so against him that he will not have money enough to double, and must therefore let his bet go. This will *probably* happen before he has won as much as he had in the first place, so that this run against him will leave him poorer than he began; some time or other it will be sure to happen. It is true that there is always a possibility of his winning any sum the bank can pay, and we thus come upon a celebrated paradox that, though he is certain to be ruined, the value of his expectation calculated according to the usual rules (which omit this consideration) is large. But, whether a gambler plays in this way or any other, the same thing is true, namely, that if plays long enough he will be sure some time to have such a run against him as to exhaust his entire fortune. The same thing is true of an insurance company. Let the directors take the utmost pains to be independent of great conflagrations and pestilences, their actuaries can tell them that, according to the doctrine of chances, the time must come, at last, when their losses will bring them to a stop. They may tide over such a crisis by extraordinary means, but then they will start again in a weakened state, and the same thing will happen again all the sooner. An actuary might be inclined to deny this, because he knows that the expectation of his company is large, or perhaps (neglecting the interest upon money) is infinite. But calculations of expectations leave out of account the circumstance now under consideration, which reverses the whole thing. However, I must not be understood as saying that insurance is on this account unsound, more than other kinds of business. All human affairs rest upon probabilities, and the same thing is true everywhere. If man were immortal he could be perfectly sure of seeing the day when everything in which he had trusted should betray his trust, and, in short, of coming eventually to hopeless misery. He would break down, at last, as every great fortune, as every dynasty, as every civilization does. In place of this we have death.

But what, without death, would happen to every man, with death must happen to some man. At the same time, death makes the number of our risks, of our inferences, finite, and so makes their mean result uncertain. The very idea of probability and of reasoning rests on the assumption that this number is indefinitely great. We are thus landed in the same difficulty as before, and I can see but one solution of it. It seems to me that we are driven to this, that logicality inexorably requires that our interests shall *not* be limited. They must not stop at our own fate, but must embrace the whole community. This community, again, must not be limited, but must

extend to all races of beings with whom we can come into immediate or mediate intellectual relation. It must reach, however vaguely, beyond this geological epoch, beyond all bounds. He who would not sacrifice his own soul to save the whole world, is, as it seems to me, illogical in all his inferences, collectively. Logic is rooted in the social principle.

To be logical men should not be selfish; and, in point of fact, they are not so selfish as they are thought. The willful prosecution of one's desires is a different thing from selfishness. The miser is not selfish; his money does him no good, and he cares for what shall become of it after his death. We are constantly speaking of *our* possessions on the Pacific, and of *our* destiny as a republic, where no personal interests are involved, in a way which shows that we have wider ones. We discuss with anxiety the possible exhaustion of coal in some hundreds of years, or the cooling-off of the sun in some millions, and show in the most popular of all religious tenets that we can conceive the possibility of a man's descending into hell for the salvation of his fellows.

Now, it is not necessary for logicality that a man should himself be capable of the heroism of self-sacrifice. It is sufficient that he should recognize the possibility of it, should perceive that only that man's inferences who has it are really logical, and should consequently regard his own as being only so far valid as they would be accepted by the hero. So far as he thus refers his inferences to that standard, he becomes identified with such a mind.

This makes logicality attainable enough. Sometimes we can personally attain to heroism. The soldier who runs to scale a wall knows that he will probably be shot, but that is not all he cares for. He also knows that if all the regiment, with whom in feeling he identifies himself, rush forward at once, the fort will be taken. In other cases we can only imitate the virtue. The man whom we have supposed as having to draw from the two packs, who if he is not a logician will draw from the red pack from mere habit, will see, if he is logician enough, that he cannot be logical so long as he is concerned only with his own fate, but that that man who should care equally for what was to happen in all possible cases of the sort could act logically, and would draw from the pack with the most red cards, and thus, though incapable himself of such sublimity, our logician would imitate the effect of that man's courage in order to share his logicality.

But all this requires a conceived identification of one's interests with those of an unlimited community. Now, there exist no reasons, and a later discussion will show that there can be no reasons, for thinking that the human race, or any intellectual race, will exist forever. On the other hand, there can be no reason against it;[1] and,

[1] I do not here admit an absolutely unknowable. Evidence could show us what would probably be the case after any given lapse of time; and though a subsequent time

fortunately, as the whole requirement is that we should have certain sentiments, there is nothing in the facts to forbid our having a *hope*, or calm and cheerful wish, that the community may last beyond any assignable date.

It may seem strange that I should put forward three sentiments, namely, interest in an indefinite community, recognition of the possibility of this interest being made supreme, and hope in the unlimited continuance of intellectual activity, as indispensable requirements of logic. Yet, when we consider that logic depends on a mere struggle to escape doubt, which, as it terminates in action, must begin in emotion, and that, furthermore, the only cause of our planting ourselves on reason is that other methods of escaping doubt fail on account of the social impulse, why should we wonder to find social sentiment presupposed in reasoning? As for the other two sentiments which I find necessary, they are so only as supports and accessories of that. It interests me to notice that these three sentiments seem to be pretty much the same as that famous trio of Charity, Faith, and Hope, which, in the estimation of St. Paul, are the finest and greatest of spiritual gifts. Neither Old nor New Testament is a text-book of the logic of science, but the latter is certainly the highest existing authority in regard to the dispositions of heart which a man ought to have.

V.

Such average statistical numbers as the number of inhabitants per square mile, the average number of deaths per week, the number of convictions per indictment, or, generally speaking, the number of x's per y, where the x's are a class of things some or all of which are connected with another class of things, their y's, I term *relative numbers*. Of the two classes of things to which a relative number refers, that one of which it is a number may be called its *relate*, and that one *per* which the numeration is made may be called its *correlate*.

Probability is a kind of relative number; namely, it is the ratio of the number of arguments of a certain genus which carry truth with them to the total number of arguments of that genus, and the rules for the calculation of probabilities are very easily derived from this consideration. They may all be given here, since they are extremely simple, and it is sometimes convenient to know something of the elementary rules of calculation of chances.

Rule I. *Direct Calculation.*—To calculate, directly, any relative number, say for instance the number of passengers in the average trip of a street-car, we must proceed as follows:

Count the number of passengers for each trip; add all these numbers, and divide by the number of trips. There are cases in which this rule may be simplified. Suppose we wish to know the number

might be assigned which that evidence might not cover, yet further evidence would cover it.

of inhabitants to a dwelling in New York. The same person cannot inhabit two dwellings. If he divide his time between two dwellings he ought to be counted a half-inhabitant of each. In this case we have only to divide the total number of the inhabitants of New York by the number of their dwellings, without the necessity of counting separately those which inhabit each one. A similar proceeding will apply wherever each individual relate belongs to one individual correlate exclusively. If we want the number of x's per y, and no x belongs to more than one y, we have only to divide the whole number of x's of y's by the number of y's. Such a method would, of course, fail if applied to finding the average number of street-car passengers per trip. We could not divide the total number of travelers by the number of trips, since many of them would have made many passages.

To find the probability that from a given class of premises, A, a given class of conclusions, B, follow, it is simply necessary to ascertain what proportion of the times in which premises of that class are true, the appropriate conclusions are also true. In other words, it is the number of cases of the occurrence of both the events A and B, divided by the total number of cases of the occurrence of the event A.

RULE II. *Addition of Relative Numbers.*—Given two relative numbers having the same correlate, say the number of x's per y, and the number of z's per y; it is required to find the number of x's and z's together per y. If there is nothing which is at once an x and a z to the same y, the sum of the two given numbers would give the required number. Suppose, for example, that we had given the average number of friends that men have, and the average number of enemies, the sum of these two is the average number of persons interested in a man. On the other hand, it plainly would not do to add the average number of persons having constitutional diseases to the average number over military age, and to the average number exempted by each special cause from military service, in order to get the average number exempt in any way, since many are exempt in two or more ways at once.

This rule applies directly to probabilities. Given the probability that two different and mutually exclusive events will happen under the same supposed set of circumstances. Given, for instance, the probability that if A then B, and also the probability that if A then C, then the sum of these two probabilities is the probability that if A then either B or C, so long as there is no event which belongs at once to the two classes B and C.

RULE III. *Multiplication of Relative Numbers.*—Suppose that we have given the relative number of x's per y; also the relative number of z's per x of y; or, to take a concrete example, suppose that we have given, first, the average number of children in families living in

New York; and, second, the average number of teeth in the head of a New York child—then the product of these two numbers would give the average number of children's teeth in a New York family. But this mode of reckoning will only apply in general under two restrictions. In the first place, it would not be true if the same child could belong to different families, for in that case those children who belonged to several different families might have an exceptionally large or small number of teeth, which would affect the average number of children's teeth in a family more than it would affect the average number of teeth in a child's head. In the second place, the rule would not be true if different children could share the same teeth, the average number of children's teeth being in that case evidently something different from the average number of teeth belonging to a child.

In order to apply this rule to probabilities, we must proceed as follows: Suppose that we have given the probability that the conclusion B follows from the premise A, B and A representing as usual certain classes of propositions. Suppose that we also knew the probability of an inference in which B should be the premise, and a proposition of a third kind, C, the conclusion. Here, then, we have the materials for the application of this rule. We have, first, the relative number of B's per A. We next should have the relative number of C's per B following from A. But the classes of propositions being so selected that the probability of C following from any B in general is just the same as the probability of C's following from one of those B's which is deducible from an A, the two probabilities may be multiplied together, in order to give the probability of C following from A. The same restrictions exist as before. It might happen that the probability that B follows from A was affected by certain propositions of the class B following from several different propositions of the class A. But, practically speaking, all these restrictions are of very little consequence, and it is usually recognized as a principle universally true that the probability that, if A is true, B is, multiplied by the probability that, if B is true, C is, gives the probability that, if A is true, C is.

There is a rule supplementary to this, of which great use is made. It is not universally valid, and the greatest caution has to be exercised in making use of it—a double care, first, never to use it when it will involve serious error; and, second, never to fail to take advantage of it in cases in which it can be employed. This rule depends upon the fact that in very many cases the probability that C is true if B is, is substantially the same as the probability that C is true if A is. Suppose, for example, we have the average number of males among the children born in New York; suppose that we also have the average number of children born in the winter months among those born in New York. Now, we may assume without doubt, at least as a closely approximate proposition (and no very nice calculation would be in place in

regard to probabilities), that the proportion of males among all the children born in New York is the same as the proportion of males born in summer in New York, and, therefore, if the names of all the children born during a year were put into an urn, we might multiply the probability that any name drawn would be the name of a male child by the probability that it would be the name of a child born in summer, in order to obtain the probability that it would be the name of a male child born in summer. The questions of probability, in the treatises upon the subject, have usually been such as relate to balls drawn from urns, and games of cards, and so on, in which the question of the *independence* of events, as it is called—that is to say, the question of whether the probability of C, under the hypothesis B, is the same as its probability under the hypothesis A, has been very simple; but, in the application of probabilities to the ordinary questions of life, it is often an exceedingly nice question whether two events may be considered as independent with sufficient accuracy or not. In all calculations about cards it is assumed that the cards are thoroughly shuffled, which makes one deal quite independent of another. In point of fact the cards seldom are, in practice, shuffled sufficiently to make this true; thus, in a game of whist, in which the cards have fallen in suits of four of the same suit, and are so gathered up, they will lie more or less in sets of four of the same suit, and this will be true even after they are shuffled. At least some traces of this arrangement will remain, in consequence of which the number of "short suits," as they are called—that is to say, the number of hands in which the cards are very unequally divided in regard to suits—is smaller than the calculation would make it to be; so that, when there is a misdeal, where the cards, being thrown about the table, get very thoroughly shuffled, it is a common saying that in the hands next dealt out there are generally short suits. A few years ago a friend of mine, who plays whist a great deal, was so good as to count the number of spades dealt to him in 165 hands, in which the cards had been, if anything, shuffled better than usual. According to calculation, there should have been 85 of these hands in which my friend held either three or four spades, but in point of fact there were 94, showing the influence of imperfect shuffling.

According to the view here taken, these are the only fundamental rules for the calculation of chances. An additional one, derived from a different conception of probability, is given in some treatises, which if it be sound might be made the basis of a theory of reasoning. Being, as I believe it is, absolutely absurd, the consideration of it serves to bring us to the true theory; and it is for the sake of this discussion, which must be postponed to the next number, that I have brought the doctrine of chances to the reader's attention at this early stage of our studies of the logic of science.

LIQUEFACTION OF GASES.[1]

By GASTON TISSANDIER.

EVERY one knows that the matter which constitutes the various natural bodies occurs in three different forms, namely, the solid, the liquid, and the gaseous states. So, too, every one knows that the state of a body is not at all immutable: a solid may be fused and volatilized; a liquid may become a solid, or be transformed into vapor; a gas may be changed into a liquid or a solid—all these changes occurring according to the conditions of temperature or of pressure to which the solids, liquids, or gases, are subjected. Water turns into ice under the action of cold; into steam under the action of heat. Sulphur, phosphorus, the metals, and most solid bodies, may in like manner assume these three states. Chlorine, protoxide of nitrogen, carbonic acid, etc., may be liquefied or solidified. To this end we have only to bring the molecules nearer to one another by compressing them, or subjecting them to the action of cold.

Faraday succeeded in liquefying a certain number of gases by compression and refrigeration, but there still remained a number that proved absolutely refractory to the most powerful agencies; hence these gases were called *permanent*. They are hydrogen, nitrogen, oxygen, carbonic oxide, bioxide of nitrogen, and formene (marsh-gas). Chemists, it is true, were quite confident that these gases, like all others, were subject to the general laws of bodies; it was held to be certain that the gases just named would, like the others, yield to sufficiently high pressure or refrigeration. But, nevertheless, they still remained bodies *sui generis*, defying, so to speak, the powers of the chemist, and their change of state presented itself as a weighty problem, the solution of which was all the more alluring in proportion to the difficulties with which it was surrounded. Berthelot, as we know, subjected them to the enormous pressure of 800 atmospheres, and to a refrigeration of more than 100° below zero, Centigrade; but all was in vain, and the permanent gases justified their name.

This is so no longer. A retired manufacturer, who at the same time is a distinguished man of science, M. Cailletet, has subdued the permanent gases, having succeeded in liquefying and solidifying them. This result, which is one of the most interesting achievements of our time, must unquestionably be regarded as a new and a grand conquest of matter by science.

Nearly at the same moment, another ingenious investigator and inventor, M. Raoul Pictet, reached the same result with regard to oxygen gas. We will pass in review successively the experiments of

[1] Translated from the French by J. Fitzgerald, A. M.

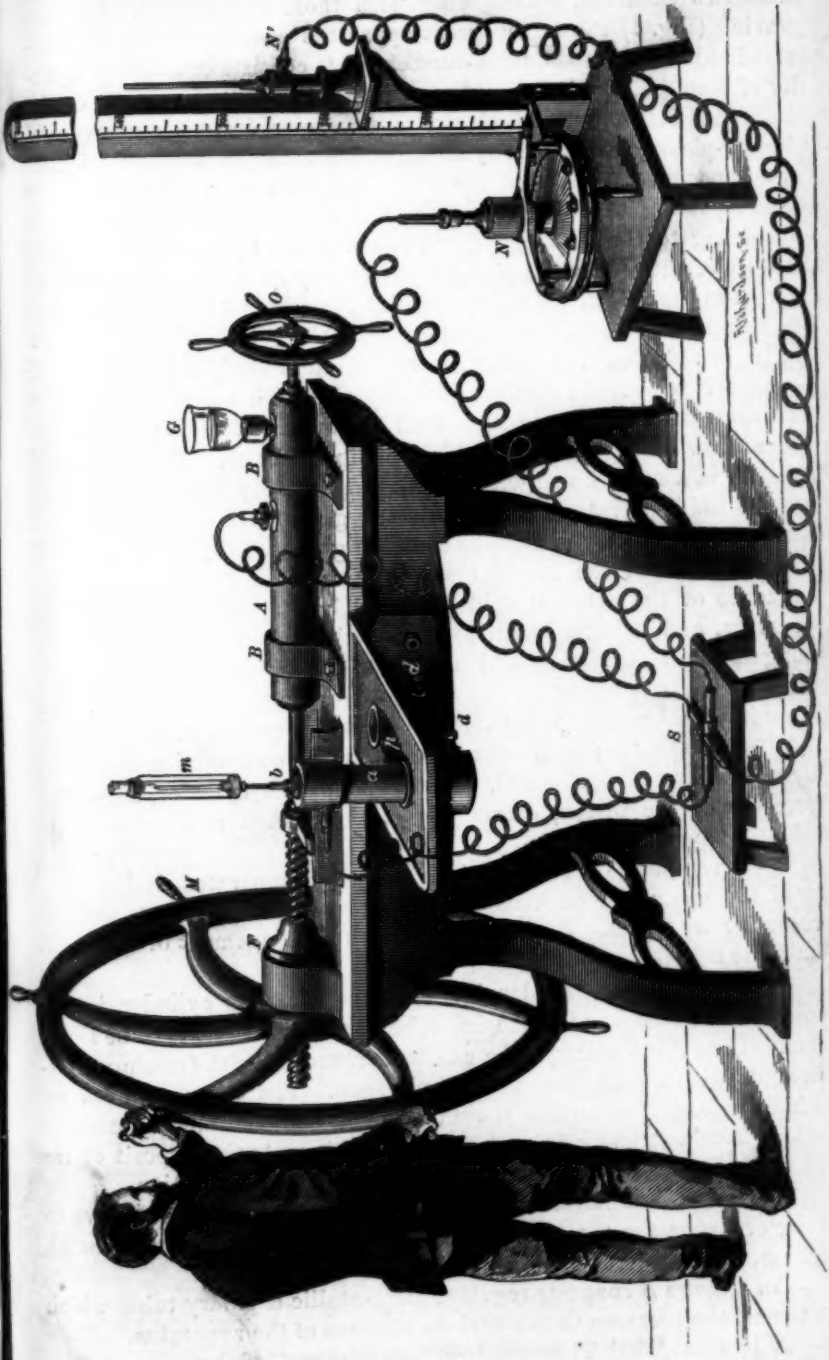

FIG. 1.—CAILLETET'S LARGE APPARATUS FOR LIQUEFYING GASES. *A*, Screw-press for compression; *m*, flint-glass cylinder inclosing the glass tube in which the gas is liquefied.

these two chemists, commencing with those of Cailletet. Our engraving (Fig. 1) shows the great apparatus constructed by M. Cailletet in his shops at Châtillon-sur-Seine. It consists of a hollow cylinder of steel, *A*, firmly secured on a bed of cast-iron by means of the clamps *B B*. A cylindrical rod of untempered steel, serving as a plunger-piston, enters this cylinder, which must be filled with water. The opposite extremity of the rod terminates in a square-threaded screw, passing through the bronze nut *F* attached to the wheel *M*. According to the direction given to the wheel by means of the pins at its circumference, the plunger-piston may be made to advance or retreat in the axis of the pump-barrel. A packing of leather prevents the compressed liquid from escaping from the cylinder.

In introducing the water, or other liquid designed to be compressed, it is poured into the glass cup *G*, which communicates with the inside of the apparatus. A steel screw, with conical point, closes the narrow passage through which the liquid enters. This screw terminates in a small wheel with handle-pins, *O*. By this arrangement we can suddenly *release* the compressed gases, and see a dense mist form in the capillary glass tube containing them. (This tube is seen in the middle of the cylinder *m*.) The mist is formed under the influence of the external cold produced by the sudden removal of pressure, and it is an infallible sign of the liquefaction, or even the congelation, of the gases which hitherto have been regarded as *permanent*.

a is a steel reservoir, capable of bearing a pressure of 900 or even 1,000 atmospheres; it is connected with the compression-apparatus by a capillary tube of metal. The water in the cylinder, under the pressure of the piston, enters this reservoir, and acts on mercury which compresses the gas.

b is the ajutage which receives the glass apparatus designed to hold the gas under experiment; it is connected with the top of the reservoir by a nut. Fig. 2 represents the arrangement of this part, half the actual size.

m is a flint-glass cylinder, inclosing another glass cylinder, in the middle of which is seen the fine tube in which the gas is to be liquefied. Thus this capillary tube can be surrounded with freezing mixtures, or with liquid protoxide of nitrogen. The outer cylinder *m*, which is concentric with the inner one, and contains substances which have a strong affinity for moisture, prevents the deposit of ice or vapor on the cooled tube, which would hinder observation.

p is a cast-iron stand to hold the reservoir *a*. Screws *d d* serve to raise or lower the reservoir for the purpose of spectroscopic examination, or of projecting the experiments on a screen.

An ajutage *S* connects together the metallic capillary tubes which transmit the pressure to the various portions of the apparatus.

N is a modified Thomasset manometer, verified by means of an

open manometer on the flanks of a hill near the laboratory of Châtillon-sur-Seine.

N' is a glass manometer which serves to check the readings of the mercurial apparatus.

This notable apparatus involves no danger, for the glass tube in which the gas is compressed presents a very small surface, and no serious result could follow were it to break.

A few years ago an English physicist, Thomas Andrews, was led to infer that, for permanent gases, there exists a *critical point* of pressure and temperature, above which they cannot be brought to the liquid state. This opinion is confirmed by Cailletet's experiments. Each gas requires that a certain pressure be combined with a certain reduction of temperature: either the one or the other of these two conditions might be employed separately without any effect, even supposing them to reach a high intensity.

The first of the permanent gases liquefied by M. Cailletet was bioxide of nitrogen. As we have just said, unless the two conditions of compression and low temperature be united according to the *critical points*, the gas does not liquefy. Hence it is that bioxide of nitrogen has remained gaseous at a pressure of 270 atmospheres and a temperature of +8° Cent. Formene or marsh-gas liquefies at 180 atmospheres and +7° Cent.

"If," says M. Cailletet, "we inclose oxygen or pure carbonic oxide in the compression-apparatus; if we reduce these gases to a temperature of −29° Cent. by the aid of sulphurous acid at a pressure of about 300 atmospheres, both gases still retain their gaseous state. But if they be released suddenly, so, according to Poisson's formula, producing a temperature of at least 200° below the starting-point, we at once see a heavy mist, caused by the liquefaction or even, perhaps, the solidification of the oxygen or carbonic oxide. The

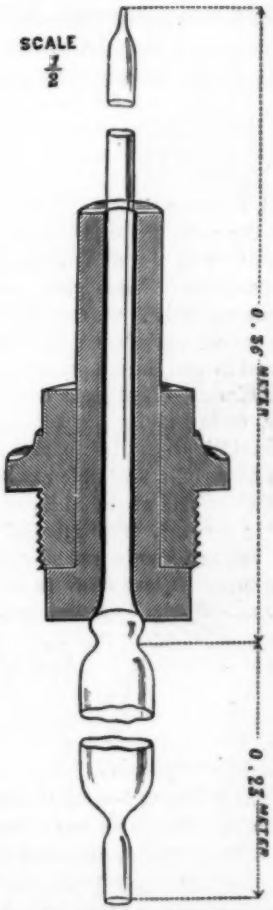

FIG. 2.—GLASS TUBE WITH THICK WALLS, IN WHICH GASES ARE LIQUEFIED. The gas is compressed in the upper part of the tube by a column of mercury forced upward by hydrostatic pressure. The gas condenses into a liquid drop or into a mist, on pressure being removed. This glass tube is inclosed within a glass cylinder holding the freezing mixture.

same phenomenon is observed in releasing carbonic acid, and protoxide and bioxide of nitrogen, which have been subjected to strong pressure."[1]

After having obtained these results, at a session of the Academy on December 31st, M. Cailletet announced that he had won a complete victory over the other permanent gases. M. Dumas informed the members present at the session that the able experimenter had succeeded in liquefying nitrogen, atmospheric air, even hydrogen itself, which would seem to have been the most refractory gas of them all.

We take from the *Comptes Rendus* the following details:

Nitrogen.—Pure or dry nitrogen, compressed under about 200 atmospheres, at a temperature of nearly +13° Cent., and then suddenly released, becomes very clearly condensed. There first appears a body resembling a pulverized liquid, in drops of appreciable volume, and then this liquid gradually disappears from the walls of the tube toward the middle, at length forming a sort of vertical column in the axis of the tube; this phenomenon persists for more than three seconds. These appearances remove all doubt as to the true character of the phenomenon. M. Cailletet first made this experiment at home with a temperature of −29° Cent.; he repeated it again and again at the laboratory of the Normal School, in the presence of several men of science.

Hydrogen.—Hydrogen has always been regarded as the most refractory of gases, owing to its slight density, and the almost complete conformity of its mechanical properties to those of the perfect gases. Hence it was with very little hopes of a favorable result that M. Cailletet subjected this gas to the same tests which had produced liquefaction of all the others.

"In my early experiments," says he, "I recognized nothing that was peculiar; but, as often happens in the experimental sciences, the habit of observing phenomena at last leads us to recognize peculiarities where before they were quite unnoticed. This was what happened in the case of hydrogen. On repeating my experiments to-day, December 31st, in the presence and with the assistance of Messrs. Berthelot, H. Sainte-Claire-Deville, and Mascart, I succeeded in observing signs of the liquefaction of hydrogen, which to these expert witnesses appeared to be unquestionable.

"The experiment was repeated many times. Hydrogen placed under a pressure of 280 atmospheres, and then released, becomes transformed into an extremely fine and subtile mist, suspended in the tube throughout its entire length, and then suddenly disappearing. The production of this mist, despite its extreme subtilty, appeared to be indisputable to all the scientific men who witnessed this experiment, and who carefully repeated it again and again, under such conditions as to leave no doubt as to the fact."

Air.—"Having liquefied nitrogen and oxygen, the liquefaction of atmospheric air was *ipso facto* demonstrated. Nevertheless, I concluded to make this a matter of direct experiment; and here, as might have been expected, I was perfectly successful. I need not say that the air had been first dried and deprived of every trace of carbonic acid. In this way," adds M. Cailletet, "was demonstrated the correctness of the views held by the founder of modern chemistry, Lavoisier, as to the possibility of reducing air to the state of *liquidity*, by producing liquids endowed with new and unknown properties."

[1] *Comptes Rendus de l'Académie des Sciences*, December 24, 1877.

Plainly, the power of producing liquid air opens to applied science new horizons. There is no need to prove that, from the purely scientific and philosophical point of view, M. Cailletet's experiments are of supreme importance.

We will conclude this article with a description of the little lecture-room or laboratory apparatus, constructed by M. Ducretet, to show how, according to Cailletet's process, gases are liquefied. It is a copy of the essential parts of the apparatus at Châtillon-sur-Seine. The bell-glass is modified. The screw-press, too, is represented here by a more portable pump. The accompanying figure, which

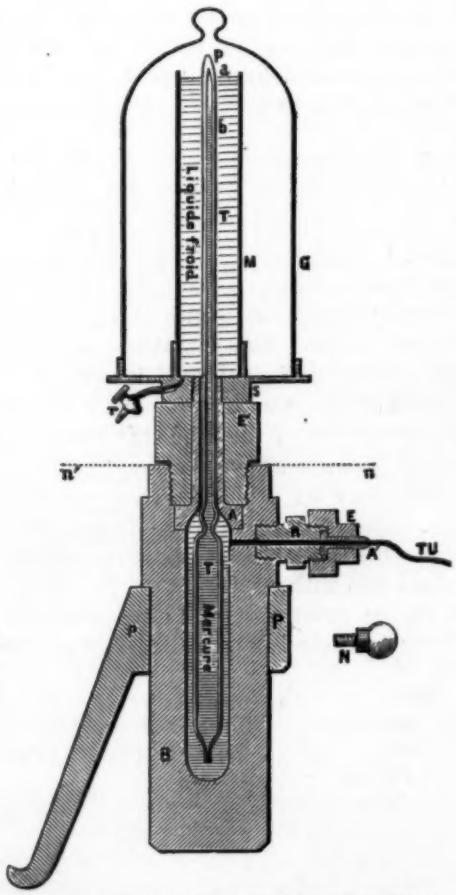

FIG. 3.—SMALL APPARATUS FOR LIQUEFYING GASES.

represents the apparatus in section, will enable us to give a more detailed description of the system devised by M. Cailletet.

T T is a glass tube, containing the gas to be compressed; a cur-

rent of the gas has passed through it, so as to expel all the atmospheric air. For this purpose it is first placed in an horizontal position; then, after it has been filled with the gas destined for the experiment, the tube is closed at its extremity *p* at a lamp, while the other extremity is closed by the finger and introduced vertically into the iron apparatus, as shown in the figure. It dips into a cylindrical reservoir of mercury. The upper part of the tube is surrounded with a glass cylinder, *M*, filled with a freezing mixture, as in the larger apparatus. The whole is then covered over with a bell-glass, *G*. The tube *TU* connects with a compression-pump, worked by hand, and provided with a manometer, which shows the degree of pressure. The water compressed by the pump acts on the surface of the mercury as seen in the figure. This mercury is thus forced into the tube *T T*, diminishes the space *a b*, occupied by the gas, and soon bears on its top little drops of compressed gas, which unite to form a small quantity of liquid, *b*.

The principal parts of the apparatus are *B*, a box of wrought-iron, with very strong walls; *E E'*, nuts which can be screwed off in order to adjust the apparatus before the experiment begins; *A*, ajutage; *P P*, two of the three very strong legs supporting the apparatus; *S*, support of the bell-glass *G* and the cylinder *M*; *N*, supplementary screw used to stop the mouth of the passage *R*, while the mercury is being poured into the apparatus.

We would remark that the enlarged lower end of the tube *T* is subject to an equal pressure within and without, and cannot break. It is only the upper portion of the tube that has to withstand the internal pressure, but its walls are very strong.

The experiment may be projected on a screen by the aid of a Drummond light. The apparatus is very simple, and liquefies a great number of gases. One can with the naked eye observe all the phases of liquefaction, and this without any danger. Hence this instrument is destined to render great service in research and in instruction, whether in colleges or in the lecture-room.—*La Nature.*

CORRESPONDENCE.

To the Editor of the Popular Science Monthly.

SIR: As a student of Herbert Spencer's Philosophy, I have waited impatiently the advent of his "Principles of Sociology," and particularly so of late, as I am greatly interested in the work of an American writer on a kindred subject. I refer to Mr. Lewis H. Morgan's "Ancient Society," lately published by Henry Holt & Co. It is to a comparison of the views of these writers on the origin of the monogamian family that I wish to invite your attention.

In Mr. Morgan's studies of consanguinity and affinity he found certain systems prevailing which could only be explained by the existence of certain forms of marriage, and of the family which produced them. These forms he has named the "Consanguine," the "Punaluan," and the "Monogamian." As before stated, it is the origin of the latter form only that I propose to discuss at present. According to Mr. Morgan, the monogamian family is comparatively modern, and came into existence with the growth of the idea of property. He says (page 477): "The growth of property and the desire for its transmission to children was, in reality, the moving power which brought in monogamy to insure legitimate heirs, and to limit their number to the actual progeny of the married pair." He maintains that exclusive cohabitation, in the sense that we understand it, was not practised until mankind had created property in masses, which they desired should pass into the hands of their offspring, and that the marriage of single pairs previous to this did not constitute monogamy, but formed what he terms the "Syndyasmian or Pairing Family," which differed from monogamy in several essential particulars, chief of which was the fact that "the marriage relation continued during the pleasure of the parties, and no longer," and, so far as the male was concerned, "the absence of an exclusive cohabitation." In reading Mr. Spencer's article on the "Evolution of the Family," it occurred to me that Mr. Morgan's theory answered his question, "Are different forms of domestic arrangement associated with the militant system of organization and the industrial system of organization?" even better than his own. Mr. Spencer remarks that, "on examining the facts more closely, we discern general connections between the militant type and polygyny, and between the industrial type and monogamy." He then calls attention to the truth that "the contrast between the militant and the industrial is properly between a state in which life is occupied in conflict with other beings, brute and human, and a state in which life is occupied in peaceful labor—energies spent in destruction instead of energies spent in production." Now it is obvious that the latter state is the one in which the growth of the idea of property and the desire to transmit it to offspring would surely be generated, and that if, as is alleged by Mr. Morgan, monogamy owed its origin to the growth of these ideas, then necessarily monogamy and industrialness would surely be connected, and that this is the case, Mr. Spencer thinks unquestioned. He says: "That advance from the primitive predatory type to the highest industrial type has gone along with advance from prevalent polygyny to exclusive monogamy, is unquestionable; and that the decrease of militancy and increase of industrialness have been the essential cause of this change in the type of family, is shown by the fact that this change has occurred where such other supposable causes as culture, religious creed, etc., have not come into play."

It seems to me that, in applying the term monogamy to all forms of the pairing family, from the highest to the lowest, Mr. Spencer is in error. He should, like Mr. Morgan, limit it to that form in which exclusive cohabitation is the law for both man and woman. He should deal with monogamy as an *institution*. In so dealing with it, we see that it has arisen, as Mr. Spencer has taught us, like all other institutions, by the action of environing agencies on existing social conditions, and that the principal agency in the present case is the growth of the idea of property.

R. M.

"THE LAW OF CONTINUITY."

To the Editor of the Popular Science Monthly.

IN reply to Mr. Launcelot's letter in the MONTHLY for February, I would draw attention to the *Journal of the Chemical Society*, volume viii., page 51, where the late Prof. Graham records certain experiments. He found that sulphuric acid continued to evolve heat when mixed even with the fiftieth equivalent of water that was added to it, so that there seemed to be no distinct limit to chemical affinity. He concludes, "There is reason to believe that chemical

affinity passes in its lowest degree into the attraction of aggregation."

As to Mr. Launcelot's paragraph, wherein he states that many metals, other than gold, have been reduced to translucent tenuity, your note makes any answer from me unnecessary. GEORGE ILES.

MONTREAL, *January* 22, 1878.

EDITOR'S TABLE.

THE PROGRESS OF AMERICAN BIOLOGY.

WE publish this month the first half of the able and interesting address delivered by Prof. Marsh, before the American Association, at Nashville, last August, on the "Introduction and Succession of Vertebrate Life in America," and which is the first complete edition that has appeared in any periodical. The paper is, from its nature, somewhat technical, but the author could not help that, as, in dealing with newly-discovered forms of life, he is compelled to use new terms a little freely, and to make his account complete he includes some lists of genera, which will be of great service to biological students, and should not frighten off unscientific readers, who will find much to interest them in the general treatment of the subject. There is nothing more remarkable in our time than the activity of its scientific thought, and the importance of the new results that are being reached in all the spheres of investigation. Of this, we have a striking illustration in the fact that four months was sufficient almost to antiquate Prof. Marsh's address, and make it necessary to post it up to the beginning of the present year, by notes from the author, stating what new things have been discovered since its delivery. Among these are mentioned a new species of fossil fish (*Ceratodus*), that has recently attracted much scientific attention, and is significant as the first found in the Mesozoic formations of this country. A number of new Jurassic reptiles, some of enormous size, and a new genus (*Epihippus*), a missing Eocene link in the genealogy of the horse, have also come to light. The interesting point here is, that these are all forms that the evolutionist was expecting from our marvelous Rocky Mountain region, and they show how rapidly the biological evidence of this theory is accumulating. The whole address is indeed a weighty contribution to the literature of this doctrine, as, besides the mere record of ancient life which it affords, the genealogies of many groups of animals are now traced for the first time. It is well known that Prof. Marsh, by his skill, enterprise, and assiduity, has made the field of the exploration of the Western fossil-beds very much his own; and in this address, which first attempts a summary statement of what is known of the extinct vertebrate life of this continent, he necessarily includes his own results. Among its leading features there is a discussion of the migrations of extinct mammals, and strong evidence is presented (in opposition to previous opinion upon the subject) that North America is really the oldest continent, from which South America, as well as Asia and Europe, derive many of their animals. The author's observations have led him also to conclude that there is at present no evidence that any of the supposed bird-tracks of the Connecticut River sandstone were made by birds, but were probably all made by reptiles. In discussing the unsettled question among geologists as to the line between the Cretaceous and Tertiary rocks in the West, Prof. Marsh puts forward a new principle or law as to the value of different kinds of fossils in determining geological age. His investigations show that the higher the grade of life, the better is the evidence

they yield; plants, for example, being poor witnesses in such a case, and the higher vertebrates the best. Geologists will be interested in the researches of the author, the results of which are also given, into the origin and succession of the Tertiary fresh-water lakes of the Rocky Mountain region; a subject upon which but little accurate information has been hitherto attainable. The portion of the paper printed in the present MONTHLY includes the fishes, amphibians, reptiles, and birds; and the second part will be devoted to the mammals, which will be discussed more in detail. Prof. Marsh has kindly prepared for us a geological section of the earth's crust, revised so as to illustrate the present aspect of the subject of the introduction and succession of vertebrate life on this continent, and which the reader will find valuable for reference in studying the address.

SOME THACHINGS OF THE TELEPHONE.

WE commend to those who persist in ventilating the ancient prejudice against the material medium of which all things around us are constituted, as "dead matter," "gross matter," "brute matter," etc., a little meditation on the remarkable powers manifested by the telephone.

In another part of the MONTHLY will be found an excellent explanation of the mechanism and mode of working of this remarkable contrivance. But, to appreciate its deeper meaning, we must recall some of the characteristics of sound and the conditions of the production of voice. The brain, the spinal centres, the nerves, and the muscles, have all to be coördinated in that expulsion of air through the apparatus of speech which results in the utterance of words. The vocal cords are thrown into vibration by the air-current which sets up wave-motions that are transmitted in all directions. To appreciate what here goes on in this light, invisible medium, we must strive to keep in mind the behavior of the air-particles. In the propagation of sound, a stream of thrills is shot out from its source, at the rate of about eleven hundred feet per second, and the series of air-waves is simply a succession of condensations and rarefactions of the elastic medium, in which the aërial particles successively take up and pass on the motions of the original impulse. According to the extent and complexity of these molecular motions is the intensity and quality of the noise. The size of the waves varies with the pitch of the sound; the first A of the bass in a piano producing air-waves about forty feet in length, while the waves of the last A of the treble are not quite four inches long. But these sound-waves are far more complex than at first seems, so that the motion of the air-particles involves something else than a mere backward-and-forward movement. A stretched string, vibrating its whole length, gives its fundamental tone, but while it thus swings as a whole, its different parts are thrown into separate and quicker vibrations, which are executed in harmonic ratio—2, 3, 4, 5, 6, 7, or 8 times—during the vibration of the whole string. These over-vibrations produce what are called overtones, which are, so to speak, drowned in the fundamental note, but which, nevertheless, serve to give it a peculiar character. It is thus that sounds from all sources acquire distinguishing marks, by which they are identified. It is by the effects of these frills, or fringes, of the larger waves, that different musical instruments, and different human voices, are distinguished from each other. The infinite varieties of sound are thus due to the subtile capacity of complex motion possessed by the air-particles. They always move exactly in the same way in the production of the same effects, and differently in yielding different effects. If we could see the dance of the air-particles when

music is executed, it would be a picture of mathematical exactness, and infinite complication, that has no analogy in anything we observe. It has always been regarded as one of the mysterious miracles of vital structure how the little membranous drum of the human ear can take up so perfectly this rapid stream of intricate motions in the air, which are all so exactly reproduced by the layer of adjacent particles striking upon the membrane, that thousands of tympanums will be all affected precisely alike, while the nerves transmit the thrills to the brain, awakening the same musical sensations and sentiments in the consciousness of as many people as can be brought within hearing. This chain of effects is wonderful, indeed; but we are now confronted with the fact, more impressively than ever, that it is no prerogative of the living organism to respond to these subtile and exquisite changes in the air; the inert, dead matter of which we hear so much—mere cold iron—will do exactly the same thing.

When we begin to use a telephone for the first time, there is a sense of oddity, almost of foolishness, in the experiment. The dignity of talking consists in having a listener, and there seems a kind of absurdity in addressing a piece of iron, but we must raise our respect for the metal, for it is anything but deaf. The diaphragm of the telephone, the thin iron plate, is as sensitive as the living tympanum to all the delicate refinements of sound. Nor does it depend upon the thinness of the metallic sheet, for a piece of thick boiler-plate will take up and transmit the motions of the air-particles in all the grades of their subtilty. And not only will it do the same thing as the tympanum, but it will do vastly more: the gross, dead metal proves, in fact, to be a hundred times more alive than the living mechanism of speech and audition. This is no exaggeration. In quickness, in accuracy, and even in grasp, there is a perfection of sensitive capacity in the metal, with which the organic instrument cannot compare. We speak of the proverbial "quickness of thought," but the telephone thinks quicker than the nervous mechanism. Let a word be pronounced for a person to repeat, and the telephone will hear and speak it a hundred miles away in a tenth part of the time that the listener would need to utter it. Give a man a series of half a dozen notes to repeat, and he cannot do it accurately to save his life; but the iron plate takes them up, transmits them to another plate hundreds of miles off, which sings them forth instantaneously with absolute precision. The human machine can hear, and reproduce, in its poor way, only a single series of notes, while the iron ear of the telephone will take up whole chords and trains of music, and, sending them by lightning through the wire, its iron tongue will emit them in perfect relations of harmony. The correlations and transformations of impulse are besides much more extended in the telephone than in the living structure. The volitional mandate from the brain incites nervous discharges, expended in producing muscular contractions that impel the air across the vibrating cords, where it is thrown into waves. But in the case of the telephone, the air-waves are spent in producing mechanical vibrations of the metal; the secreate magnetic disturbances, which excite electrical action in the wire, and this again gives rise to magnetic changes that are still further converted into the tremors of the distant diaphragm, and these finally reappear as new trains of air-waves that affect the listener, while the whole intermediate series of changes is executed in a fraction of the time that is required by the nervous combinations of speech. And not only does the telephone beat the living machine out of sight in speed, accuracy, compass of results, and multiplicity of dynamical

changes, but it distances it also in the simplification of its resources. The same bit of dead metal serves equally for both ear and tongue; the offices of the diaphragm are interchangeable, and the machine works backward and forward with exactly the same facility.

The lesson here taught is, that we are to elevate our conceptions of the powers of matter. Science is making constantly fresh revelations of its potencies and capacities, and we are probably still only upon the threshold of this world of wonders.

CONCERNING THE BELIEF IN HELL.

A LIVELY discussion has recently been carried on by the pulpit and the press as to whether there is a future state of eternal torment. Two or three eminent orthodox clergymen spoke out in rather strong denunciation of the idea, and this was followed by an epidemic of controversy. Certain people seem to have been perplexed as to what is meant by so free a handling of a solemn old subject. We think it simply means that people have been thinking about it until expression is a relief, and that many have reached conclusions that they are glad to have a chance of ventilating. There has been, thanks to the influence of science, a pretty rapid liberalizing of theological opinion during the past generation; and this discussion about hell is an instructive indication of the advance that has been made.

The question of the existence of a veritable hell is, of course, a theological one, which we cheerfully leave to those interested, but the topic has also a scientific side. The rise and course of the *idea*, or what may be called the natural history of the belief in hell, is a subject quite within the sphere of scientific inquiry. It is legitimate to ask as to how the notion originated, as to its antiquity, the extent to which it has been entertained, the forms it has assumed, and the changes it has undergone, and from this point of view it of course involves the principle of evolution. We cannot go into so large a discussion here, but as this is an aspect of the subject not much dwelt upon, a few suggestions regarding it may not be inappropriate.

In the first place, it is necessary to rise above that narrowness of view which regards the doctrine of hell as especially a Christian doctrine, or as the monopoly of any particular religion. On the contrary, it is as ancient and universal as the systems of religious faith that have overspread the world. The oldest religions of which we have any knowledge—Hindoo, Egyptian, and the various Oriental systems of worship—all affirm the doctrine of a future life, with accompanying hells for the torture of condemned souls. We certainly cannot assume that all these systems are true, and of divine origin; but if not, then the question forces itself upon us, how they came by this belief. The old, historic religious systems involved advanced and complicated creeds and rituals, and if they were not real divine revelations in this elaborated shape, we are compelled to regard them as having had a natural development out of lower and cruder forms of superstition. To explain these religions—as to explain the earliest political institutions—we must go behind them. There is a prehistoric, rudimentary theology of the primitive man, the quality of which has to be deduced from his low, infantine condition of mind, interpreted by what we observe among the inferior types of mankind at the present time.

It is certain that early men, in profound ignorance of the surrounding world and of their own natures, must have grossly misinterpreted outward appearances and their internal experiences, and analysis of the conditions has abundantly shown how these primitive misunderstandings led inevitably to manifold superstitions. Herbert

Spencer, in his "Principles of Sociology," recently published, has carefully traced out this working of the primitive mind, and explained how the early men, by their crude misconceptions of natural things, were gradually led to the belief in a ghost-realm of being appended to the existing order. The idea of a life after death, so universally entertained among races of the lowest grades of intelligence, is accounted for, and is only to be accounted for, in this way. Through experiences of sleep, dreams, and loss and return of consciousness at irregular times as in swoon, catalepsy, trance, and various forms of insensibility, there grew up the idea of a double nature—of a part that goes away leaving the body lifeless, and returns again to revivify it; and thus originated the theory of immaterial ghosts and spirits. At death the ghost departed, but not to return and reanimate the body in the usual way; it went to inhabit another place. Thus arose the conception of a separate and future life, which, at first, could not have been supposed to differ much from that of the present order of things. No doubt what is said of the Fijians, that after death "they plant, live in families, fight, and, in short, do much as people in this world," represents the common beginnings of belief upon this subject. Yet the hope of better things could not fail to come soon into play, as indicated by the belief of the Creeks, that after death they go where "game is plenty, and goods very cheap; where corn grows all the year round, and the springs of pure water are never dried up." Von Tschudi tells us that in Peru "a small bag with cocoa, maize, quinua, etc., is laid beside the dead that they might have wherewithal to sow the fields in the other world." The condition of the future life, where the ghosts go to dwell, is believed to be so similar to that which they have left that it is almost universal among savages to bury food, weapons, implements, ornaments, clothing, and whatever they may be likely to want, with the bodies of their dead friends. Even dogs and cattle are slain, and women and servants immolated, that they may accompany and minister to the departed.

But this bald conception of a future life, as a kind of literal continuance of present materialities, could not last. As knowledge accumulated the conception grew incongruous, and underwent important modifications, so that similarity gradually passed into contrast. The intimacy of the intercourse supposed to be carried on between the two worlds decreased; the future world was conceived of as more remote, and as having other occupations and gratifications more consonant with developing ideas of the present life. Rude conceptions regarding good and evil could not fail to be early involved with considerations of man's futurity. Good and evil are inextricably mixed up in this world, which seems always to have been regarded as a faulty arrangement, and, as there was little hope of rectifying it here, the future life came to be regarded as compensatory to the present. But the problem was solved, not by the absorption and disappearance of evil, but by supposing good and bad to be mechanically separated; and, as good and bad means good people and bad people, the belief arose that in the future world they would be divided off, the good being all collected in a good place, and the bad ones all turned into a bad place.

This idea of using the next world to redress the imperfections and wrongs of this grew up early and survives still, and it has exerted a prodigious influence in human affairs. As the grosser superstitions were gradually developed into systematic religions, a priestly class arose, and religious beliefs were embodied in definite creeds. Fundamental among these was the belief in heaven as a place of happiness, and of hell as a place of penal torment for the wicked.

To one or other of these places, it was held, all men are bound to go after death; but to which depended — and here the office of the priesthood assumed a terrible importance, for they knew all about it, and had the keys. It is impossible to conceive any other idea of such tremendous power for dominating mankind as this! It raised the priesthood and ecclesiastical institutions into despotic ascendency, brought it into unholy alliance with civil despotisms, and became the mighty means of plundering the people, crushing out their liberties, darkening their hopes, and cursing their lives. So productive an agency of unscrupulous ambition could not fail to be assiduously cultivated, and the conception of hell, the most potent element in the case by its appeal to fear, was elaborated with the utmost ingenuity. Language was exhausted in depicting the terrors of the infernal regions and the agonies of the damned. We by no means say that these ideas were mere priestly inventions, but only that they grew up under the powerful guidance of a class consecrated to their exposition, and incited by the most powerful worldly motives to strengthen their influence. In order to enforce belief, to compel obedience to ecclesiastical requirements, to coerce civil submission, and to extort money, people were threatened with the horrors of hell, which were pictured with all the vividness of rhetorical and poetic fanaticism. As the hierarchical spirit grew in strength, and became a tyrannical rule, obedience to its minutest rites was enforced by the most appalling intimidations. To neglect some trivial ceremony was sufficient to incur damnation. Alger says, in his "History of the Doctrine of a Future Life:" "The Brahmanic priest tells of a man who, for neglecting to meditate on the mystic monosyllable Om before praying, was thrown down into hell, on an iron floor, and cleaved with an axe, then stirred in a caldron of molten lead till covered all over with the sweated foam of torture, like a grain of rice in an oven, and then fastened, with head downward and feet upward, to a chariot of fire, and urged onward with a red-hot goad."

In noticing the causes of the extent, influence, and perpetuity of this sombre belief, we must not forget that the future life, being beyond experience and inaccessible to reason, offers an attractive play-ground for the unbridled imagination. It opens an infinite realm for sensuous imagery and creative invention, stirs the deepest feelings, and concerns itself with the mystery of human destiny. It accordingly offers a favorite topic for poetic treatment, and this is more especially true of the darker aspects of the future world, poets having ever taken with avidity to delineations of hell. From Hesiod to Pollok, pagans and Christians have vied with each other in their poetical representations of the tortures and terrors of the infernal state. The mythological form of the doctrine figures largely in the great epics of Greece and Rome; the Italian "Inferno" pictures the Christian hell with terrible intensity, and the grand poem of the English language, "Paradise Lost," has hell at the root of its plot, and hell's master for its hero. Homer, Virgil, Dante, and Milton, working through poems of immortal genius that have fascinated mankind, some of them through thousands of years, and others through centuries, have thus combined to familiarize countless millions of people with the conception, and to stamp it deep in the literature of all countries.

Yet the doctrine of hell is now growing obsolete. Originating in ages of savagery and low barbarism, and developed in periods of fierce intolerance, sanguinary persecutions, cruel civil codes, and vindictive punishments, it harmonized with the severities and violence of society, and undoubtedly had use as a means of the harsh dis-

cipline of men when they were moved only by the lowest motives. But, with the advance of knowledge, and the cultivation of the humaner sentiments, the doctrine has become anomalous and out of harmony with the advance of human nature. Hence, though still a cardinal tenet of orthodoxy, it is now generally entertained in a vague and loose way, and with reservations and protests that virtually destroy it. Only revival preachers of the Moody type still affirm the literal "lake of fire and brimstone," and it is certain that the doctrine in any shape recurs much less prominently in current preaching than it did a generation or two ago. Sober-minded clergymen have got in the way of neglecting it, except now and then when rehearsing the creed, or, as at present, under the spur of controversy, or when rallied about the decay of the old theology. The hell of Jonathan Edwards is gone. That sturdy theologian wrote: "The world will probably be converted into a great lake, or liquid globe of fire—a vast ocean of fire in which the wicked shall be overwhelmed, which will always be in tempest, in which they shall be tossed to and fro, having no rest day or night, vast waves or billows of fire continually rolling over their heads, of which they shall forever be full of a quick sense within and without: their heads, their eyes, their tongues, their feet, their loins, and their vitals, shall forever be full of a glowing, melting fire fierce enough to melt the very rocks and elements; and also they shall eternally be full of the most quick and lively sense to feel the torments; not for one minute, nor for one day, nor for one age, nor for two ages, nor for a hundred ages, nor for ten thousands of millions of ages, one after another, but for ever and ever without any end at all, and never, never be delivered."[1]

This is sufficiently explicit, but no man of the rank of its author talks in such a strain nowadays. In the current pulpit utterance there is a perfect chaos of discordant speculation, open repudiation, tacit disavowal, and ingenious refining away, but no stern and sturdy defense of it, in the old form and spirit, from any source that commands respect. The doctrine of hell is still conserved in popular creeds, but, if not eliminated, it will be pretty certain to carry the creeds with it into the limbo of abandoned superstitions.

[1] Edwards's Works, vol. viii., p. 166.

LITERARY NOTICES.

PESSIMISM: A HISTORY AND A CRITICISM. By JAMES SULLY, M. A. London: C. Keegan Paul & Co., 1877. Pp. 470.

MR. SULLY, who is already well known for his investigations of æsthetic feeling from the psychological point of view, here undertakes to give us an account of the modern pessimistic philosophy which has spread so widely of late years in Germany, and also thoroughly to criticise its basis, its procedure, and its results. He begins with an analysis of the two antithetical frames of thought among the unphilosophic public which he aptly designates as "unreasoned optimism and pessimism." By the first of these terms Mr. Sully understands that joyous and vigorous view of life which belongs to moments of exaltation, or to the constitutionally happy; by the opposite expression he means the gloomy standpoint which we all naturally assume in periods of grief or depression. Passing on from these primitive and unsystematic beliefs, each the transitory expression of a fleeting emotional tone, our author traces the growth of a more deliberately pessimistic creed through the literature of Hebrew and classical antiquity, the middle ages, and the modern world. Next, he attacks the various forms of "reasoned optimism and pessimism," the conscious attempts to appraise the worth of the universe as absolutely good or bad. The origin of evil is shown to be the main problem which the optimistic Israelitish religion set itself to solve; while the pessimistic tendencies of Aryan thought in India, reaching its furthest development in Buddhism, are well pointed out. Through Greece and Rome,

Mr. Sully proceeds to the optimistic philosophers of the last century, who endeavored, by metaphysical subtilty, to argue the existence of evil out of the universe. Of this school, Leibnitz, Shaftesbury, and Pope, may be taken as the leaders. The French *éclaircissement* brought a new idea to the front, that of human perfectibility, personified in Condorcet and Godwin. It was hoped that, after all, evil might not be inherent in the nature of things, but might prove a mere excrescence, due to the social errors of mankind. This creed found its most eloquent exponent in the poet Shelley; and, extravagant as were its first enthusiastic developments, Mr. Sully justly traces to its influence the modern belief in progress as an actual fact, present and prospective. In the social amelioration promised by the apostles of evolution, and especially by Mr. Herbert Spencer, our author rightly sees "the one vital type of optimism in our age." The kernel of the work is reached when we come to the survey of Schopenhauer's philosophy, and the account of his disciple, Hartmann, whose system is very fully analyzed. Their deliberate conviction, arrived at by an ostentatiously logical and stringent method, consists in the belief that "life is a uselessly interrupting episode in the blissful repose of the non-existent." With the careful exposition of their teaching, the historical portion of Mr. Sully's volume closes. The larger and critical division consists of a systematic dialectic against the whole argument of German pessimism, as represented by these its greatest lights. Into this part of his work, which is lengthy, and closely reasoned, we can only briefly follow him. Mr. Sully begins by clearly setting forth the problem in dispute. He then attacks the superstructure of Hartmann from its metaphysical basis, which he shows to be verbal, illusory, and self-contradictory. Its scientific basis is next examined from the physical and the psychological standpoints; and from both it is found to be wanting. Finally, the author sums up his own view in three somewhat lengthy chapters, which exhibit him as holding a middle course between the two extremes. While he rejects the untenable theory of the absolute optimists, he cannot agree that any groundwork for pessimism as a reasoned principle exists in the facts under consideration. His own platform is summed up in the single expression *meliorism*, suggested to him by George Eliot. In this creed he finds an incitement to practical effort which falls in with the natural longings of humanity and the teachings of modern evolutionism, but which is wanting either to the satisfied theological optimist or to the blankly-despondent German pessimist. In the hopes of our common humanity we have a refuge alike from the selfish acquiescence of the pietist and the petty troubles of individual existence.

As a whole, the work exhibits all Mr. Sully's characteristics in their fullest form. It is rather long-winded, a trifle dull, and somewhat apt to stray from the plain paths of common-sense into the hazy realm of metaphysics and casuistical subtilty. But, on the other hand, it is full of varied and accurate learning, judicial impartiality, and studied moderation. Great pains have been taken to bring it up to date in every respect, some works being actually noticed or quoted which must have appeared while the volume was passing through the press. And as an exhaustive account of all that has been written or thought upon its subject at all periods, ancient or modern, it may be thoroughly recommended alike to the psychological student and to the general reader.

THE ANCIENT LIFE-HISTORY OF THE EARTH. A Comprehensive Outline of the Principles and Leading Facts of Palæontological Science. By H. ALLEYNE NICHOLSON, M. D., D. Sc., Professor of Natural History in the University of St. Andrew's. D. Appleton & Co. Pp. 407. Price, $2.00.

THE subject of this book is one of growing scientific interest. Only within the present century has it been revealed that the earth has been laden with life for untold ages, until its crust has become a vast tomb, and even thick and extensive rock-strata are made up of the skeletons of creatures of extreme minuteness. The present life of the globe is but the last term in an almost infinite series of generations, that have so varied in form and character, as we go back in time, that they serve to mark off the geological epochs.

A group of absorbing questions now clusters around this great fact of the ancient life-history of the earth, and there is much

concern among multitudes of thoughtful people to acquire some clear and correct ideas upon the subject. Fierce controversies have sprung up in relation to it, which are liable so to vitiate the statements of conflicting parties, that many are at a loss to know what representations they can trust, and how to get at the unquestioned facts. To all persons in this state of mind, Dr. Nicholson's work will be especially welcome, as it is a clear, succinct, and dispassionate account of the present state of palæontological knowledge, or of its descriptive parts independent of the contested theories to which it has given rise. His book is, moreover, compendious in form, and moderate in cost, to a degree that is quite unusual in a work so profusely and elegantly illustrated. Its preparation has involved great and careful labor, and the artists have done it excellent justice in the skill and fidelity of their pictorial representations. We know of no other volume that will so well meet the wants of a large class of readers at the present time. An excellent feature of the book is its copious bibliography or literature of reference appended to the leading chapters. In the appendix there is a tabular view of the chief divisions of the animal kingdom, followed by an ample glossary of technical terms, and a very full index.

AN AMERICAN GIRL, AND HER FOUR YEARS IN A BOYS' COLLEGE. By SOLA. New York: D. Appleton & Co. Pp. 269. Price, $1.50.

THIS book records the experiences of a young lady who got a craze to go to college, and when a certain collegiate institution took off the embargo upon feminine opportunity, and admitted girls to the regular course of study, she argued her mother into consent, and entered the establishment. She has adventures, mishaps, exploits, and a lively time generally, both in doors and out. The book is written with considerable spirit, and conveys a very good idea of college-life, in its feminine aspect. The writer is somewhat critical of many things, but believes profoundly in women going to men's colleges. In the sequel, she gets married to one of the students, the circumstances of love-making, while in college, being duly presented; but what possible or conceivable bearing the course of study pursued had upon the prospective life of the woman, who passed from the valedictory platform to the hymeneal altar, appeareth not in this book of "An American Girl."

MONEY. By FRANCIS A. WALKER. New York: Henry Holt & Co. Pp. 550. Price, $4.

IT is no disparagement to a book of this kind to state that it covers no new ground: efforts after originality in the treatment of subjects of this class are seldom successful or profitable. It is high, but in this case well-deserved, praise to be able to say that it is impartial in its statements, judicial in its conclusions, and full, clear, and exact, in its explanations — the presentation, as a whole, of the much-vexed question of money being popular and comprehensible.

The book will be a valuable one, because, among other reasons, the author has allowed himself space in which to classify his subject fully, and to elaborate details in a way to bring out likenesses and differences that the casual reader is likely to overlook.

There are three general divisions: Part I., "Metallic Money," under which head the function and distribution of money, the production of the precious metals, their coinage and circulation, are considered. Chapters XII., "The Concurrent Circulation of Two Metals," and XIII., "The Battle of the Standards," are of great present interest. They constitute a full and exceedingly fair presentation of the opposed views of the bi-metalists and the mono-metalists. The author emphasizes the fact, often lost sight of, that the question is one into which political considerations enter so largely, that it will be difficult, if not impossible, to settle it on strictly economic principles. Indeed, throughout the book the important influence of legislation, habit, sentiment, and other the like factors, upon economic affairs is more fully recognized than is usual in such treatises. Part II. is devoted to "Inconvertible Paper-Money." Its theory is stated and historically illustrated. The chief danger of its use is seldom better stated than in the following paragraph: "The danger of over-issue is one which never ceases to threaten an inconvertible paper-money. The path winds even along the verge of a precipice. Vigilance must never be relaxed. The prudence and self-restraint of years count for nothing, or

count for but little, against any new onset of popular passion, or in the face of a sudden exigency of the Government. From this danger a people receiving into circulation an inconvertible paper-money can never escape. A single weak or reckless administration, one day of commercial panic, a mere rumor of invasion, may hurl trade and production down the abyss."

This and Part III., on "Convertible Paper-Money," are able discussions, and timely, for we fear they are over-sanguine who think that the day of our danger from paper inflation is past.

Mr. Walker discards altogether the word currency, for reasons which he gives fully, and which are not without force. He also substitutes the term "common denominator of exchange" for "measure of value," in defining one of the functions of money—a change which we indorse without reservation. There is a copious index, and the book is in all respects well gotten up.

MONEY AND LEGAL TENDER IN THE UNITED STATES. By H. R. LINDERMAN, Director of the Mint. New York: G. P. Putnam's Sons. Pp. 173. Price, $1.25.

THERE is given to the public in this little book a brief but comprehensive history of American coinage, by a man thoroughly conversant with his subject, and competent to point out clearly the lessons to be drawn from our experience.

The various laws regulating the coinage and the workings of the mint are given. The terms used in treating of bullion, coinage, and money, are defined. A short chapter states what constitutes a legal tender.

Accounts are given of the paper-currency since 1863, of fractional notes, coin-certificates, funding operations, etc.

Beginning with page 100 is a discussion of the proposition to remonetize silver. It is a straightforward, common-sense statement of the question, stripped of illusions and technicalities, that we should be glad to see widely circulated.

In the appendix are conveniently tabulated useful statistics concerning the production of silver, its use, movements, and prices, the ratio between it and gold, the coinage of the United States mints, etc.

It would be hard to find a book better adapted to clear away the fogs, which just now beset the subject of currencies and standards, than this volume of Dr. Linderman's, if the public could only be induced to read it.

AN EPITOME OF THE POSITIVE PHILOSOPHY AND RELIGION EXPLANATORY OF THE SOCIETY OF HUMANITY IN THE CITY OF NEW YORK, TOGETHER WITH THE CONSTITUTION AND REGULATIONS OF THAT SOCIETY; TO WHICH IS ADDED AN IMPORTANT LETTER OF HARRIET MARTINEAU IN REGARD TO HER RELIGIOUS CONVICTIONS. Second edition. Pp. 59. Published by the Society of Humanity, 141 Eighth Street, New York.

THIS pamphlet will interest many as an exposition, in brief, of the religious basis of positivism. A society has been formed in New York devoted to these ideas, and this is its platform or confession of faith, various points of which are elucidated, and numerous authorities quoted, who have expressed sentiments in sympathy with the ideas here presented. It is an earnest and well-written document, evidently by a thorough-going adherent of the system, and is by no means strictly confined to the considerations of religious questions. It contains some new schemes or charts, presenting classifications and methodical arrangements of scientific and philosophical ideas that are filled out with a symmetrical completeness which seems to leave no room for improvement. The blank squares are all filled up so that the system looks finished, and there seems to be a perfect correspondence between the geometrical spacings of the map and the divisions of human knowledge. These tabular arrangements are, however, undoubtedly not designed to be final, but to be open to future revision, and they are of a very suggestive nature. Into the theological questions raised by this *brochure* we cannot now enter, but may note the manifest humility of the new sect, as there is not a name to be found of anybody connected with it, or of the authorship or publication of the manifesto, or of any human personality, representative of the "society." This is somewhat remarkable, as the propagandists of the new faith of Positivism are somewhat notorious for their free handling of personalities with whom they differ; and it seems still more surprising when we remember that the religious polity of positivism is so

full of the apotheosis of individuals, and has such a copious calendar of saints, and makes men the objects of its worship.

GERRIT SMITH: A BIOGRAPHY. By OCTAVIUS BROOKS FROTHINGHAM. New York: G. P. Putnam's Sons. Pp. 381.

WHETHER this work is to be regarded as a success will depend upon the ideal formed of what a true biography ought to be. If we accept the Boswellian standard, which makes biographical excellence to consist in the copiousness of gossip, trivial particulars, and idle tattle about its subject, Mr. Frothingham's volume must be pronounced a failure. Such details are usually not only worthless, if true, but, originating in a spirit of adulation, they are generally so partial and false as to be of little use for any serious purpose. Moreover, the cast of mind that can produce such books is pretty certain to be wanting in the insight, the analytic capacity, and the critical judgment, necessary to form a true estimate of character.

Mr. Frothingham's book has not been made on this model. Though strictly a biography, that is, the description of a life, and though freely delineating those circumstances, incidents, peculiarities, sayings, and habitual actions, which mark and define the personality he is dealing with, yet all such details are made subordinate to the purpose of so unfolding and representing the nature of the man that readers may form their own judgment respecting his greatness. Thus regarded, the book is able, eminently successful, and worthy of its subject. Gerrit Smith was a most admirable man, a noble-hearted philanthropist, who put his great fortune at the service of society, and devoted his life to the skillful management of his immense wealth, that he might dispense it for beneficent ends. He was a radical and thorough-going reformer, taking deep interest in all projects of moral amelioration, such as peace, temperance, antislavery, and other philanthropic schemes, for which he worked with vigor, and which he aided liberally with his means. He was also from youth an uncompromising democrat, living plainly, carrying out his theories of practical equality, and never betrayed into the aristocratic ostentation which he might have indulged on an imposing scale. The radicalism of his nature, moreover, asserted itself strongly in his religious experience. Beginning as a devoted Christian of the orthodox stamp, he held steadily to the practical observances of a pious life, but gradually freed himself from the trammels of theology, and, at length, emerged as a liberal Christian of the extremest sort. Christianity was with him a purely practical affair, a carrying out of the principles of human brotherhood, and the extending of sympathy and help to all who needed them. Doctrinal matters were therefore held lightly, and he told somebody late in life that he had not yet made up his mind whether he had a soul or not. In a variety of respects his character and position were unique, and his career altogether forms a study of special interest to those concerned with the philosophy of charities and benevolence.

TRANSCENDENTALISM, WITH PRELUDES ON CURRENT EVENTS. By JOSEPH COOK. J. R. Osgood & Co. Pp. 305. Price, $1.50.

THIS book emanates from the same mind that wrote the "Biology," and is, probably, of similar quality. Osgood well knows the length of his customers' ears, and puts in the "applause" all the same.

PUBLICATIONS RECEIVED.

Cerebral Hyperæmia. By W. A. Hammond, M. D. New York: Putnam's Sons. Pp. 108. $1.

The Nabob. By A. Daudet. Boston: Estes & Lauriat. Pp. 456. $1.50.

Foundations. By J. Gaudard. New York: Van Nostrand. Pp. 104. 50 cents.

Democracy in Europe. By Sir T. E. May. New York: W. J. Widdleton. 2 vols., pp. 495 and 568. $5.

Comparative Psychology. By J. Bascom. New York: Putnam's Sons. Pp. 296. $1.50.

State Regulation of Vice. By A. M. Powell. New York: Wood & Holbrook. Pp. 127. $1.

Journal of the Academy of Natural Sciences of Philadelphia. Vol. VIII., Part III. (New Series).

Bulletin of the Minnesota Academy of Natural Sciences. Minneapolis: Young & Winn print. Pp. 126. 50 cents.

Annual Report of the Pennsylvania Training School for Feeble-minded Children. West Chester, Pa.: Hickman print. Pp. 35.

Proceedings of the Association of Medical Officers of Institutions for Idiots. Philadelphia: Lippincott & Co. Pp. 35.

The Young Scientist. Monthly. Pp. 12. 50 cents per year.

Magazine of American History. January, 1878. New York: Barnes & Co. Pp. 64. With steel-plate Portrait.

Report of the New Jersey Commissioners of

Fisheries. Trenton: Naar, Day & Naar print. Pp. 63.

Report of Trustees of West Pennsylvania Institution for Deaf and Dumb. Pittsburg: Stevenson, Foster & Co. print. Pp. 32.

Is the Human Eye changing its Form? By Dr. E. G. Loring. New York: The Author. Pp. 25.

The Steppes of Southern Russia. By Th. Belt. Pp. 20.

A New Type of Steam-Engine. By R. H. Thurston. From *Journal of the Franklin Institute*. Philadelphia: Kildare print. Pp. 35.

Medical Education in the United States. By N. S. Davis, M. D. Washington: Government Printing-Office. Pp. 60.

Reports of Curators of Wesleyan University Museum. Middletown, Conn.: Pelton & King print. Pp. 30.

Pneumono-Dynamics. By G. M. Garland, M. D. New York: Hurd & Houghton. Pp. 155.

Bulletin of the American Geographical Society, No. 4. New York: The Society. Pp. 105.

Public Health. By G. P. Conn, M. D. Concord, N. H.: Republican Press Association print. Pp. 17.

Convergent Strabismus. By S. Theobald, M. D. Baltimore: Foster print. Pp. 10.

Pseudocyesis and Pregnancy. By J. W. Underhill, M. D. New York: Wood & Co. Pp. 18.

Reports of Examinations of the New York Insurance and Banking Departments. New York: Green print. Pp. 30.

Dietetics of Infants. By T. Moore, M. D. Philadelphia: Sherman & Co. print. Pp. 14.

Report of Director of Harvard College Observatory. By Prof. E. C. Pickering. Cambridge: Wilson & Son print. Pp. 36.

New Double Stars. By S. W. Burnham. From "Notices of Royal Astronomical Society." Pp. 3.

Album Leaves. By G. Houghton. Boston: Estes & Lauriat. Pp. 34. 35 cents.

Notes on Matters of Physical Astronomy. By L. Tronvelot. From "Proceedings of the American Academy of Arts and Sciences."

POPULAR MISCELLANY.

The Last of the Gases.—The last of the gases that had never been condensed to liquids—oxygen, hydrogen, and nitrogen—have at length yielded to pertinacious experiment, and, under the joint influence of greater degrees of cold and pressure than had ever before been employed, have been reduced to the liquid form. This great experimental exploit has been performed by two chemists independently, and almost simultaneously — Raoul Pictet, of Geneva, and M. L. Cailletet, of Paris, by different processes. Pictet condensed oxygen, which was first announced; but Cailletet had already done it, and he also liquefied nitrogen, hydrogen, and the air. We give a representation of his apparatus, and an account of his processes, and shall give fuller statements of the results as they are more fully announced.

Stanley's Trip down the Congo.—The exploration of the Congo River from Nyangwe to the sea, by Henry M. Stanley, must be esteemed one of the most important achievements in the whole history of African discovery. He set out on November 5, 1876, from Nyangwe (latitude 4° 20′ south, longitude 26° 40′ east), at the head of a numerous band of native followers, marching northward by land forty miles, till he again came to the river—known here as the Ugarowa, or the Lualaba. Putting his men in canoes, and himself embarking on the portable Lady Alice, he commenced his long journey of alternate boating and portaging which lasted for nine months. The party soon began to experience the hostility of the native tribes, who again and again attacked them from the banks of the stream or in canoes. On December 6th seventy-two of Mr. Stanley's men were down with smallpox, which rendered defense all the more difficult; he seized a town, and there housed his sick and wounded, but for two days and nights he and his party had to repel the fierce attacks of the natives. Soon he was boating down the river again, his force on January 4th numbering 146 men. In latitude 0° 32′ 36″ south is a series of cataracts, and Stanley's men had to cut a road through the forest and drag their canoes round the falls, the natives constantly harassing them in the mean time. Just below these cataracts the river widens enormously, receiving several considerable affluents; its course, too, becomes westerly, though still tending toward the north till it reaches latitude 1° 40′ north, longitude 22° east, when it takes a southwesterly direction to the sea. One of the great tributaries of the Congo below the cataracts is the Aruwini, supposed to be the Welle of Schweinfurth. Here, on Stanley's map, is the legend "The Cannibal Region," and a little to the south "The Region of Dwarfs." At one place the expedition was attacked by the cannibals in fifty-four canoes with paddles eight feet long, spear-headed and pointed with iron blades. Stanley's breech-loaders soon forced the enemy to retreat in confusion. After receiving, in latitude 0°

20′ south, longitude 19° 40′ east, the waters of a great river, Ikelembo, otherwise the Kasai, coming from the south, and a little below, another river from the north, the Congo flows southwesterly in a mighty stream, till at the mouth of the Kwango it is compressed between two ranges of hills. The rapids commence 180 miles above Yellala Falls, there being a series of sixty-two cataracts; these it took the party five months to pass. Mr. Stanley reached the coast on August 11th with the ragged and half-starved remnant of his followers, having followed the river for about 1,800 miles. They were received on board a British naval vessel, and the natives carried back to Zanzibar. Mr. Stanley himself has returned to England.

German Handicraft.—A correspondent of the *Manufacturer's Review*, now visiting Germany, cites numerous facts confirming the criticisms passed by Prof. Reuleaux upon the quality of the work done by German artisans. Last winter, this writer occupied a room richly furnished and decorated, but hardly a day passed without some accident happening. The ornaments were all glued on, and one day it was the cornice of a wardrobe, another the slat of the dressing-table, that fell off. Not a single lock in the bureau would hold a drawer closed. On a windy night a match was extinguished by a gust of air coming through the *double windows*. This case was typical. "Whenever," says the author, "I had occasion to call in an artisan, the job was badly done, or delayed, or bungled. I never had a suit of clothes or a pair of boots that fitted." His experience extended over all Germany, both north and south, in small villages and towns up to 25,000 inhabitants, and it was everywhere the same. The best specimens of German manufacture are exported, as the home market requires cheap goods. Now, as the author remarks, Germany is preëminently the land of technical education, and the question naturally arises, "Is this the fruit of the system, and is the system itself a failure?" Various answers have been given: "It has been pointed out that as domestic industry has no use for them, a large number of the skilled, technically educated artisans and workmen emigrate to where their services are better appreciated, and that they are to be found in the workshops of Paris, London, and New York, occupying leading and well-paid positions. There is undoubtedly a great deal of truth in that, but it is also evident that it fails to cover the case; the cause must be deeper. It has been asserted, by men who certainly ought to know, that the instruction in German technical schools is too purely theoretic and scientific, and too little practical; that the professors, able men though they be, often have no practical knowledge of the arts of which they expound the underlying principles. It is evident that in this way the students, instead of being trained, are spoiled for their work. To illustrate, you need simply look at some of our American agricultural colleges; the professors may be excellent chemists, physicists, botanists, and zoölogists, but how many of them know practically anything about farming? It is thus that the question I have discussed has a practical bearing upon our own institutions. We are beginning to introduce technical schools everywhere, and we must guard against the danger mooted."

The Whitney Glacier.—While visiting the Pacific slope, on business of the United States Entomological Commission, Mr. A. S. Packard, Jr., ascended Mount Shasta, in Northern California, and studied the Whitney Glacier, one of the three glaciers on its flanks. The Whitney Glacier is about three miles long, and extends from the summit of Shasta peak down to or quite near the line of trees. The surface is white and clean near the top. Ice cascades and crevasses begin very near the upper termination. On the upper portion on the east side, under a perpendicular wall of rock, is a lateral moraine; and a little farther down, where the glacier abuts against the crater-cone of Mount Shasta, is a lateral moraine on the west side. The terminal moraine covers the bottom of the glacier, and connects the two lateral moraines. The end of the glacier, instead of being free of detritus, pushing the mass before it, as in most European glaciers, runs under the terminal moraine for a considerable distance, the ice here and there projecting above the surface of the moraine. At and beyond the end of the

present terminal moraine lies the former extension of it, constituting naked plains; and below the still more ancient moraine, showing the former size of the glacier, and comprised of a series of well-wooded hills. A muddy stream runs north from the end of the glacier.

Sensitiveness of the Leaves of the Common Teasel. — On closely examining the glandular hairs of the leaves of the common teasel, Mr. Francis Darwin observed protruding from them translucent, highly-refracting threads, capable of spontaneous movement. These filaments were found to consist of protoplasm, containing a large amount of resinous matter. They not only possess the power of spontaneous movement, but can also be made to contract violently under the influence of sundry reagents, of temperature, electricity, or simple mechanical irritation. In nutritive fluids the movements are very remarkable. Thus, in an infusion of meat, the filaments became rounded or sausage-shaped, or very long and bulky; sometimes they coalesced with one another, or again became completely detached and floated freely in the fluid. The movements resemble the "aggregation movements" observed in the tentacles of the *Drosera*. Mr. Darwin is of the opinion that these anomalous structures are connected both with the production of resin and the absorption of nitrogenous matter. In the adult teasel the leaves form, by their union in pairs across the stem, large cups, in which water collects, and in which insects are caught. The decomposing bodies of these insects form with the water a strongly-nutritive fluid, which is absorbed by the gland-hairs and their filaments.

Gas as a Domestic Fuel.—Gas as a fuel for domestic use possesses many noteworthy advantages over all other kinds of fuel, and there is, apparently, nothing to hinder its universal substitution in place of grosser fuels, save its greater cost. By using a gas-apparatus, we may do away with dust, smoke, ashes, cinders, and kindling-material, save time and labor, and escape many vexations. For summer use, gas-stoves possess special advantages even on the ground of economy. "It is desirable," says the *American Gaslight Journal*, "to keep as cool during the heated term as is consistent with the pecuniary and mechanical means at our command; therefore, we should have our artificial heat so arranged as to be used only when desired for active work, and employed no longer than is necessary. With a good apparatus, the gas actually used for cooking and performing all necessary fuel-labor, during the warm season, costs no more than the coal and kindling used for the same purposes, and we get the comfort, saving of time, convenience, and sanitary influence, thrown gratuitously into the trade." The case is different when it is proposed to employ gas for the purpose of warming houses. "It is," the *Journal* admits, "more expensive to run a gas-stove for a given amount of heat than it is to run a coal-stove for the same. Hence, when the heat is to be continuous, the coal-stove has the advantage so far as cost is concerned." Our contemporary then suggests to the gas companies the advisability of setting up in houses of gas-consumers a special metre connected with the heating and cooking apparatus, and of selling gas for these purposes at half-price, so as to encourage the use of gas in this way.

Impure Water fatal to Fish-Breeding. —Mr. Seth Green takes advantage of an accident which occurred lately at the State fish-ponds, to caution people against drawing off the water of old mill-ponds, except they do it very slowly, especially in warm weather. "Last week," he writes to *Forest and Stream*, "the State ponds at Caledonia came near losing all their breeding-fish. The head of the stream is about one mile above the ponds. Half of the water comes out of the ground at the head of the stream, and a dam was put across the creek sixty years ago, about forty rods from the spring, making a pond of several acres. It is full of moss and all sorts of animalcula. Last week the owner of the pond opened the gates, and let the water down with a rush. It killed all the trout in the stream for a half-mile below, and if it had not been for many large springs coming in on both sides of the creek, all the trout in the stream and ponds would have been killed, and it would take many years to restock the ponds as

they now are." The different kinds of fish now in these ponds are California salmon, Kennebec salmon, brook-trout, salmon-trout, grayling, a hybrid of California salmon and brook-trout, also a hybrid between salmon-trout and white-fish.

Graves of the Mound-Builders. — On opening a sepulchral mound on Coup's Creek, Macoupin County, Illinois, four skeletons were found sitting two-and-two, with the arms crossed, and the knees of one pair pressing sharply against the backs of the other. The grave was six feet in length by three in width, and search was made for other remains. Nothing, however, was found, except four large marine-shells, identified as of the Linnæan species *Busycon perversum*. The position of each of these shells in relation to the skeletons was the same: the smaller end of one had been placed in the right hand of each, while the larger portion rested in the hollow above the left hip. But what will appear most singular in this remarkable find is the fact that each shell contained what seemed to be the bones of an infant. "Within each of the shells," writes Mr. John Ford, in the "Proceedings" of the Academy of Natural Sciences of Philadelphia, "there had been packed what appeared to be the bones of a child; the skull, which evidently had been crushed before burial, protruding beyond the aperture. Of course, any hypothesis regarding the purpose of this peculiar rite must necessarily be of a conjectural character; nevertheless, it was difficult to resist the conclusion that these infants were sacrificial offerings to the spirits of the dead, whom the living desired to honor."

Non-Poisonous Coloring for Preserved Vegetables.—A patented process, for giving to cooked and preserved vegetables a green color, without the employment of copper or any other poisonous substance, is described as follows: First, the green leaves of some such plant as spinach, or sorrel, are scalded for a few minutes with boiling water, and drained; they are then triturated with knives or other cutting instruments. Next the triturated mass is heated with an equal weight of caustic soda solution marking 12.5° Beaumé, the mixture being boiled till the leaves are dissolved. From the product prepare a "lacker" by precipitating alum with this alkaline solution of chlorophyl, and then draw off and wash the precipitate in abundance of water, and finally press out the excess of water. To prepare the lacker for use, about thirty pounds of it is put in a basin with about fifteen pounds of soluble phosphates, especially phosphates of soda, potash, or ammonia, or of acid phosphates, or alkaline citrates, or double tartrates, and water is added until the liquor marks 2° to 5° Beaumé. To communicate the green color of this chlorophyl preparation to cooked or preserved vegetables, the latter have only to be immersed for a few minutes in the solution at a temperature of 212° Fahr. The effect of the operation is to impart to the products treated a fine, permanent green color, due to the absorption and fixation of an excess of chlorophyl.

Compressed Air in Coal-Mining.—An English journal gives an account of certain experiments recently made at Wigan to show how compressed air may be substituted for fiery explosives in coal-mining. A "cartridge," or reservoir, was placed in a shot-hole, after the manner of a charge of powder, and rammed or plugged in the same way. This chamber is in connection with a powerful air-pump, adapted expressly for the purpose, and, by simply turning a wheel, the collier can "fire his shot" without the least danger of setting fire to the inflammable gases. Mr. Marsh's (the inventor's) machine is capable of exerting a pressure of over 12,000 pounds to the square inch, and this force can be produced by two men turning the wheel in less than three minutes from the time of ramming the cartridge. The Wigan experiments show that very large quantities of coal can be brought down at a very much less expenditure of force. The first cartridge "fired" was burst at a pressure of 7,500 pounds to the square inch, the pressure being registered by a gauge. The coal was fractured, but not brought down; and a second cartridge was inserted, and burst at a pressure of 8,250 pounds to the square inch, completely loosening the coal and breaking up about eight tons. The whole force of the shot was probably not exerted on the seam, as

the ramming was blown out. The machine is described as very handy and compact, and easily used, while the cost, beyond the first outlay, is absolutely *nil*.

The Heliotype Process.—For some years an eminent publishing-house in Boston has been engaged in the production of "heliotype" copies of famous works of art, and the public is now more or less familiar with the products of the "heliotype" process. But what that process is we have nowhere seen explained till recently a writer in the *Tribune* gave a very intelligible account of its *modus operandi*. In what follows we propose to give in brief the main points of the author's explanation: First a photographic negative is made in the ordinary manner; but the "positive" plate is peculiar. The basis of its composition is gelatine, with a mixture of bichromate of potash and chrome alum. This mixture is dissolved in hot water, and the solution is then poured on a plate of glass or metal, and left to dry. When dry it is about as thick as ordinary parchment, and is stripped from the plate and placed in contact with the previously-prepared negative; the two are then exposed to the light. The bichromate of potash makes the gelatine plate sensitive to light, and wherever the light touches it the plate becomes leathery or water-proof. The result of the exposure to light is, therefore, that a portion of the gelatine plate—the image—is water-proofed, while the remainder is absorbent of water. Now, we know what a repulsion exists between water and greasy substances of every kind—for instance, printer's ink. It follows that, if we moisten the gelatine plate, the unchanged parts will absorb the water, and, if ink is then rolled over it, it will adhere only in the altered parts. By so applying ink, the sheet of gelatine is converted into a "positive" plate from which copies can be taken on a printing-press. This plate, strange to say, is very durable, and is capable of yielding, with fair treatment, several thousand impressions. Of course, the sheet of gelatine must have a solid base given to it, to hold it firmly on the bed of the press while printing. This is accomplished by uniting it under water with a metallic plate, exhausting the air between the two surfaces, and attaching them by atmospheric pressure.

Epidemics and Ablution.—A short time ago we published some remarks of Dr. Hebra, of Vienna, depreciatory of the value of frequent bathing. A diametrically opposite opinion is held by the eminent hygienic reformer, Edwin Chadwick, C. B., who cites facts to prove that skin-cleanliness, or in other words frequent ablution of the whole person, is a powerful preservative against all infectious and contagious diseases. He asserts that in children's institutions the death-rate and cases of sickness have been reduced one-third by regular head-to-foot ablutions with tepid water. Experienced trained nurses, regularly attending scarlatina-patients, give themselves regular head-to-foot ablutions twice a day, and a change of clothes once a day. Medical men of experience, who serve amid plagues and the most terrible epidemics, do the like. Mr. Chadwick adds: "If I had again to serve as a member of a general board, and had to exercise authority in providing defenses against epidemics, I would propose regulations for the immediate and general 'tubbing' of the population, and have it seen to as sedulously as vaccination for protection against small-pox." To show the influence of skin-cleanliness on the assimilation of food, Mr. Chadwick relates the following incident: "A friend of mine," he writes, "in command of a brigade in Spain, was hemmed in, and his men were put on very short rations; and to amuse them—it being summer-time—he encouraged them to bathe daily in a river close by, and he marked, as a result he had not expected, that his men were in as good strength as the unwashed soldiers on their full rations." Similar results are observable in the inmates of well-kept prisons.

New Process of Embalming.—A new and inexpensive method of embalming has been invented by Dr. Lowell, of Brooklyn. The preservative fluid he employs is a solution of zinc chloride which is injected into the body either by an artery or a vein. The apparatus required consists of a porcelain-lined vessel, which is elevated to such a height that the solution may be injected into the cadaver after the manner of a gravity-syringe. For the passage of the preservative fluid from this receptacle into the vein of the cadaver, glass and rubber

tubing is all that is required. Dr. Lowell writes: "The injection may be made by either artery or vein. . . . I prefer the brachial artery above the elbow as the point for introduction of the glass tube, for the primary incision is slighter, and consequently divides smaller and fewer veins than when I expose the femoral artery. I use the gravity method, and introduce about five gallons of the antiseptic fluid. The effects are eminently satisfactory. The color of the integument is improved." A body treated in this way was transported from New York to Richmond last summer without odor, disfigurement, or external sign of decay.

NOTES.

THE Count de Saporta has discovered in the Silurian rocks of Angers the remains of ferns—the first evidence so far found in Europe of the existence of terrestrial vegetation during Silurian times. In the American Silurian formation Prof. Leo Lesquereux had already found fern-remains.

PROF. WILLIAM DWIGHT WHITNEY, of Yale College, has been named a member of the French Academy of Inscriptions and Belles-Lettres.

AN interesting law case lately came before a London magistrate, namely, the violation by a gas company of the act of Parliament which fixes the maximum of impurity permissible in illuminating gas. The company defendant were sued to recover *eight penalties* of £50 each for having on eight days supplied gas of less purity than the act allows. The court ordered a warrant to issue for the full amount of penalties claimed.

WE have to record the first instance that has come under our notice of a house-owner being arrested and held to account in New York City for neglecting duly to provide against the entrance of poisonous sewer-gases into his tenements. In January, an agent of the Board of Health sued out a warrant against a house-owner who had offended in this way, and the accused was bound over for examination. The Health Board is to be commended for its action in this case, and encouraged to go on with the good work.

DIED at Paris, December 20th, Henri Daniel Ruhmkorff, aged about seventy-five years. He was by birth a Hanoverian, but came to Paris at a very early age, and there spent the remainder of his life. He was first a porter in a physical laboratory, where he acquired a taste for electrical experiments. He soon opened a little shop for making physical apparatus. His famous magneto-electric "coil" was produced in 1851; in 1858 he received for it the first prize of 50,000 francs at the French Exhibition of electrical apparatus.

MR. E. A. BARBER, in the *American Naturalist*, notes a singular rite formerly practised by the Seminoles at the "christening" of their male children. At the age of fourteen the boy was scratched or incised with a sharp flint six times on each arm and leg, the length of the incisions being about a foot. If the lad flinched or cried out, he received an insignificant name; but if he bore the pain manfully, he received a high-sounding title, and was destined to become a great man in the tribe.

THE statistics of rainfall at San Francisco for the past twenty-five years or more are contradictory of the theory according to which the amount of rainfall is in direct proportion to the number of spots on the sun. It has been shown by Mr. J. S. Hittell that during the four years from 1865 to 1869 there was at San Francisco a total fall of 118 inches—the greatest quantity ever noted there for an equal period—and yet those four years were "in the minimum portion of the sun-spot cycle." The table of annual rainfall given by Mr. Hittell is in fact, as far as it goes, an evidence that there is no periodicity either of maximum or minimum rainfall at San Francisco.

THE advantages of crying and groaning in pain are set forth by a French physician, who holds that these modes of expression are Nature's own methods of subduing the keenness of physical suffering. He would have men freely avail themselves of this means of numbing their sensibility during surgical operations. Crying in children should not be repressed, for, according to this authority, such repression may result in very serious consequences, as St. Vitus's dance, epileptic fits, etc.

A BAKER in Paris having used, for heating his oven, painted wood from old houses which had been torn down in opening a new street, many persons who ate the bread were seized with violent symptoms of lead-poisoning. The heat converted the paint into pulverulent oxide of lead, which adhered to the moist surface of the loaves. The men who brushed these loaves were the first to suffer, and then all who ate the crust experienced with more or less intensity the agonies of "painters' colic." A police regulation has been issued forbidding the use by bakers of wood from old houses.

P. ANGELO SECCHI.